PAM & SAM System User's Manual

Part 1 - Selecting System Components

Ordering Number: 9032 011 981

Issue September 13, 2000

This version replaces all previous versions of this document. It also replaces the SAM System Designer's Guide (1995-1996). Inmotion Technologies and ACC Motion have made every effort to insure this document is complete and accurate at the time of printing. In accordance with our policy of continuing product improvement, all data in this document is subject to change or correction without prior notice.

ACC Motion SA
Zone industrielle La Rippe
CH-1303 Penthaz
Switzerland

P/n 9032 011 981
Issue September 13, 2000

© 1995 - 2000
by ACC Motion SA
All rights reserved

Table of Contents

Table of Contents....3
List of Figures....5
List of Tables....5
Introduction....7
Component Selection Procedure....7
Overview of System Components....8
PAM and its Accessories....11
Selecting the PAM Model....11
PAM Accessories....12
EasyBus Connections....12
AC Supply and Earthing....16
About International AC Supply Voltage Standards....16
Selecting SAM Units that fit to AC Supply....16
Accommodating Multiple AC Supply Voltages....17
Earthing Requirements....18
Motors....19
Motor Technology Choices....19
Motor Selection....19
Special Purpose Motors....20
Position Feedback Devices....22
Position Feedback Device Types and Characteristics....22
Using a 2nd Position Feedback Device....28
Selecting Compatible Feedback Devices....28
SAM Drives....30
Introduction....30
Determining Axis Current Requirement....32
Position Feedback Options....34
Brake Control Option....34
User I/O Options....35
Mating Cables and Plugs for SAM Drives....37
General Information....37
Motor Windings Cable Assemblies....38
Feedback Cable Assemblies....40
DC bus Cable Assemblies....40
Selecting Mating Plugs....41
SAM Supply and its Accessories....42
Introduction....42
Estimating DC Bus Power Requirement....43
SAM Supply Selection Based on Power Requirements....46
Selecting an External DB Resistor....47

SAM Supply Unit Accessories 48
Additional DC-bus Capacitors 52
Quick DC-bus Discharge 52
Feeding Section 53
General 53
Basic Feeding Section Configuration 54
EMC Filter 55
Inrush Current Limiting Components 55
Optional Transformer 57
Circuit Breaker, Fuses, Relays and Wiring 57
24 VDC Supply 58
System Enclosure 59
Cabinet Selection 59
Cooling Equipment 60
Appendix A - Mating Plugs Specifications 61
Appendix B - Cables 65
Appendix C - DC-bus alternatives 66

List of Figures

Figure 1 PAM with SAM System Component Selection Process 7
Figure 2 PAM with SAM System Components.....8
Figure 3 PAM with SAM System Components.....11
Figure 4 EasyBus Cables Link a PAM and SAM Drives in a Closed Ring 13
Figure 5 Motor Selection Procedure 19
Figure 6 Reading Motors Characteristic Curves 20
Figure 7 Resolver Output amplitude as a function of angle 22
Figure 8 Incremental Digital Encoder Output 24
Figure 9 Incremental Sine-Cosine Encoder Output 24
Figure 10 Incremental Sine-Cosine Encoder with Commutation Track 26
Figure 11 General Procedure for Selecting a SAM Drive 30
Figure 12 SAM Drive Model Numbering Key 31
Figure 13 Continuous and Peak Current Requirements for Example.....33
Figure 14 SAM Drive Cable Assemblies and Mating Connectors.....37
Figure 15 General Procedure for Selecting a SAM Supply.....42
Figure 16 SAM Supply Model Numbering Key.....43
Figure 17 SAM Supply Mating Connector Configuration 49
Figure 18 DC bus bar wiring diagram 50
Figure 19 DC-bus bar outlines 50
Figure 20 Contact principle 51
Figure 21 Basic Feeding Section Components.....54
Figure 22 Power mating plug drawings for marking specification.....63
Figure 23 Signal mating plug drawings for marking specification.....64

List of Tables

Table 1 PAM Configurations and Intended Applications 12
Table 2 EasyBus Cable Ordering part numbers 13
Table 3 EasyBus Cable Properties and Selection criteria 14
Table 4 Standard AC Supply Voltages that are compatible with SAM 16
Table 5 Resolver Characteristics Summary....23
Table 6 Incremental Sine-Cosine Encoder Characteristics Summary....25
Table 7 Mutli-turn Absolute Sine-Cosine Encoder Characteristics Summary 27
Table 8 Multiturn Resolver Characteristics Summary....28
Table 9 SAM-Compatible Rotary Feedback Devices 29
Table 10 SAM-Compatible Linear Feedback Devices 29
Table 11: SAM Drive selection and ordering information (large drives are available only with brake output option) 31
Table 12 Feedback Devices and Combinations for Option P5N 34
Table 13 Standard and Expanded User I/O configuration 35
Table 14 Current carrying capacity for various conductor cross sections at 40 oC 38
Table 15 Correction factor as a function of ambient temperature....38
Table 16 8-conductor Motor Windings Cable Selection and Ordering information 39
Table 17 4-conductor Motor Windings Cable Selection and Ordering information 39
Table 18 Feedback Cable Selection and Ordering information (5 meter) 40
Table 19 SAM Drive Mating plug selection and ordering information....41
Table 20 SAM Supply selection and ordering information....43
Table 21 SAM Supply Model Selection Chart....47
Table 22 External DB Resistance Selection and Ordering part numbers....48
Table 23 DC-bus bar data....51
Table 24 Basic Feeding Section Component list 55
Table 25 SAM 24 VDC current requirements 58
Table 26 PAM Mating Plugs....61
Table 27 SAM Supply Mating Plugs 61
Table 28 Cabling Accessories Plugs 62
Table 29 SAM Drive Mating Plugs 62
Table 30 PAM and SAM System recommended Cables 65

Introduction

Component Selection Procedure

Figure 1 presents a logical sequence of steps for selecting PAM with SAM system components and accessories. It is based on the fact that certain system components must be selected before others. Proceed sequentially through the tasks in Figure 1, branching when necessary to the referenced topics that contain the details.

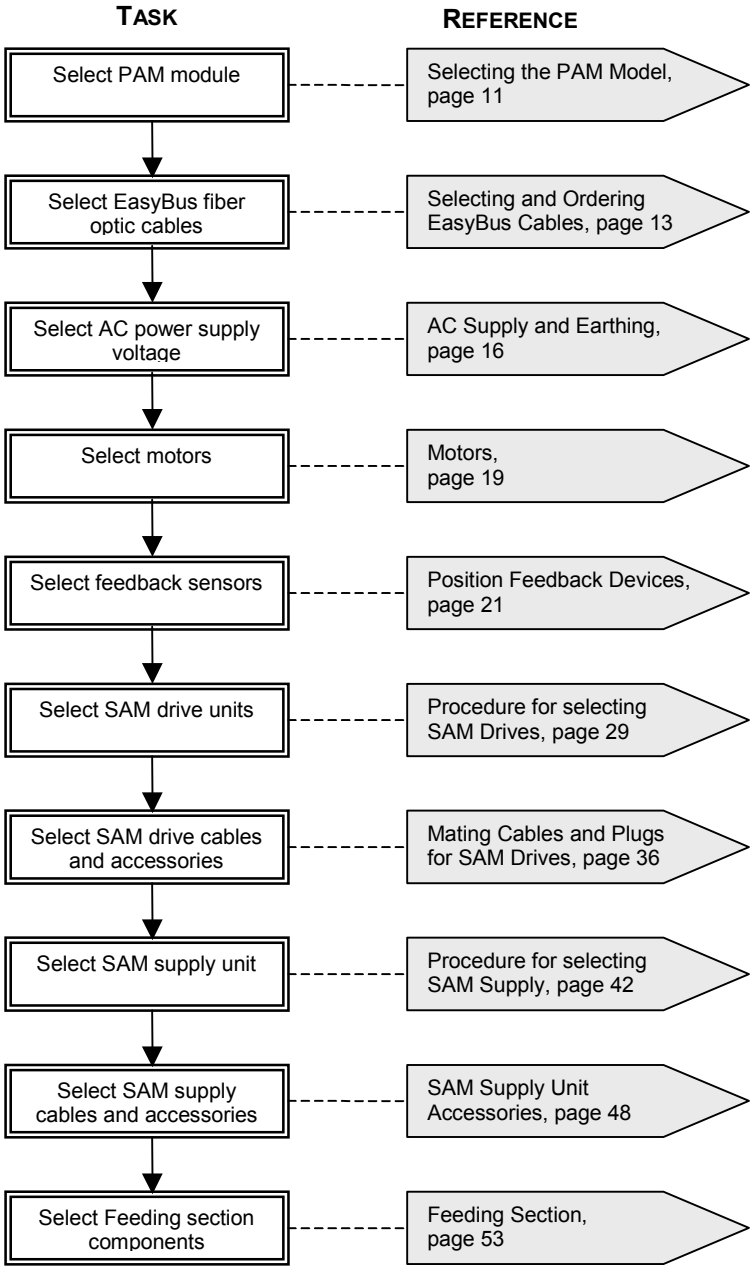

TASK
REFERENCE
Select PAM module
Selecting the PAM Model, page 11
Select EasyBus fiber optic cables
Selecting and Ordering EasyBus Cables, page 13
Select AC power supply voltage
AC Supply and Earthing, page 16
Select motors
Motors, page 19
Select feedback sensors
Position Feedback Devices, page 21
Select SAM drive units
Procedure for selecting SAM Drives, page 29
Select SAM drive cables and accessories
Mating Cables and Plugs for SAM Drives, page 36
Select SAM supply unit
Procedure for selecting SAM Supply, page 42
Select SAM supply cables and accessories
SAM Supply Unit Accessories, page 48
Select Feeding section components
Feeding Section, page 53

Figure 1 PAM with SAM System Component Selection Process

Overview of System Components

PAM with SAM System Configuration

Figure 2 illustrates a three-axis PAM with SAM system. Many other configurations are possible depending on the specific requirements of an application. Most machine control systems include a PC/PLC and an operator control station (MMI) for overall machine control. The following paragraphs provide brief descriptions of the principal functions of each PAM with SAM system component.

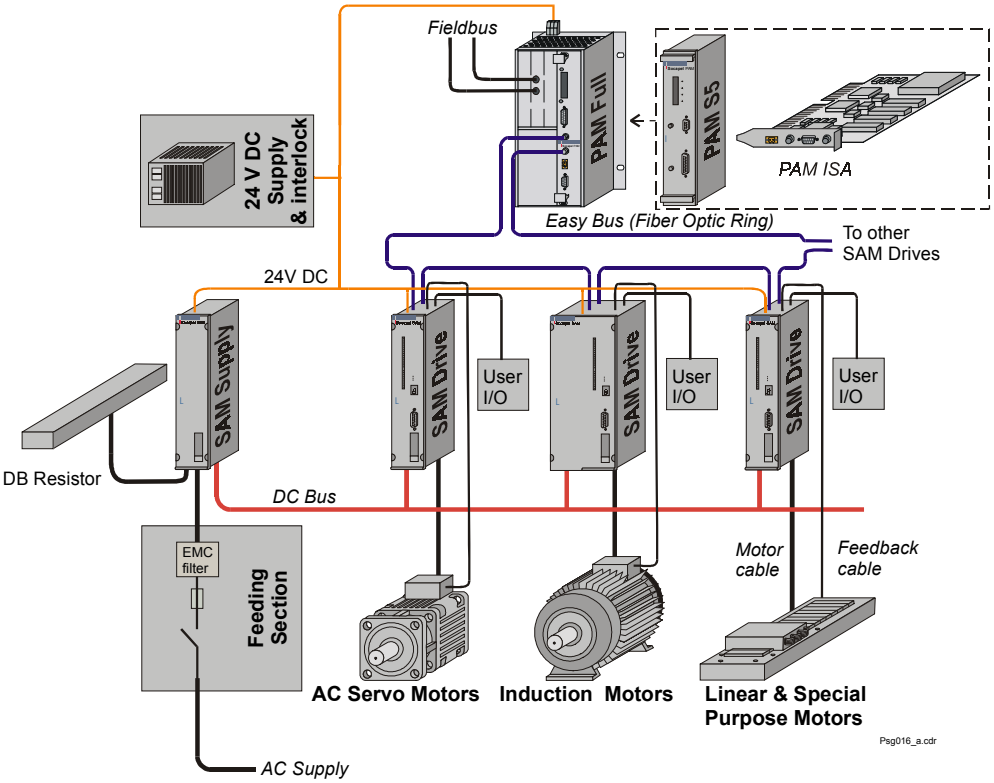


Figure 2 PAM with SAM System Components

PAM

The PAM (Programmable Axis Manager) is the system's control and motion coordination center. PAM controls motion, I/O and program flow as dictated by the application program under execution. PAM may be linked to a host PC, PLC or factory automation system for hierarchical control and reporting using one of a number of industry standard communications network interfaces. PAM is supplied in three packaging configurations, mounted in a rack, as module for insertion into a Simatic PLC and as an ISA board for direct installation in a PC.

EasyBus

This is a high speed fiber-optic bus that links PAM and all SAM Drives in a closed ring configuration for exchange of program, status I/O and motion information.

SAM Drive

The SAM Drive is a modern, high performance digital motion controller with an integral power stage. SAM Drives execute motion, I/O and program tasks in response to data and commands from PAM, providing enhanced system performance through distribution and sharing of system functions. SAM Drives are available with continuous power output ratings of 1.5 up to 30 kVA for controlling AC servomotors, and other special purpose motors. Any SAM Drive may be operated at 400 or 480 VAC.

SAM Supply

The SAM Supply provides rectified DC power to each SAM Drive at a voltage proportional to the AC supply voltage. The SAM Supplies are available in two versions for operation at 400 and 480 VAC respectively.

Motors

Motors convert electrical power from a SAM Drive to mechanical power. AC servo motors and other motor types including linear and direct drive motors are readily interfaced with SAM Drives.

Feedback Devices

A feedback device coupled to each motor provides the SAM Drive an indication of the motor's shaft angle, for use in commutating the motor and controlling its speed and position. The feedback device is usually integrated into the motor. A number of feedback devices including resolvers and incremental sine/cosine encoders or rulers are supported.

Motor and Feedback Cables

The motor cable transmits the SAM Drive's three phase power output to the motor windings. The feedback cable carries power and data for the feedback device.

AC Supply

The AC Supply provides the power that (following conversion) is applied to the axis motors by the SAM Drives.

DC Bus

The DC Bus distributes a SAM Supply's high DC current, high voltage output to SAM Drives. A compact DC bus bar system is available.

DB Resistor

The DB (Dynamic Braking) Resistor dissipates excess energy returned to the DC Bus. In some configurations, the DB Resistor is located internal to the SAM Supply.

24 VDC Supply and Interlocks

This 24 VDC power source supplies logic power to the PAM, SAM Drives and SAM Supply. The same supply often powers other machine functions.

Feeding Section

The necessary main power switching, protection and safety components are represented as a single block called the “Feeding Section”.

PAM and its Accessories

Selecting the PAM Model

General Procedure

PAM is available in a number of packaging configurations and with a number of popular network interfaces. The type of host controller and network interface required primarily determines the appropriate model PAM for an application. Table 1 summarizes the applications for each configuration.

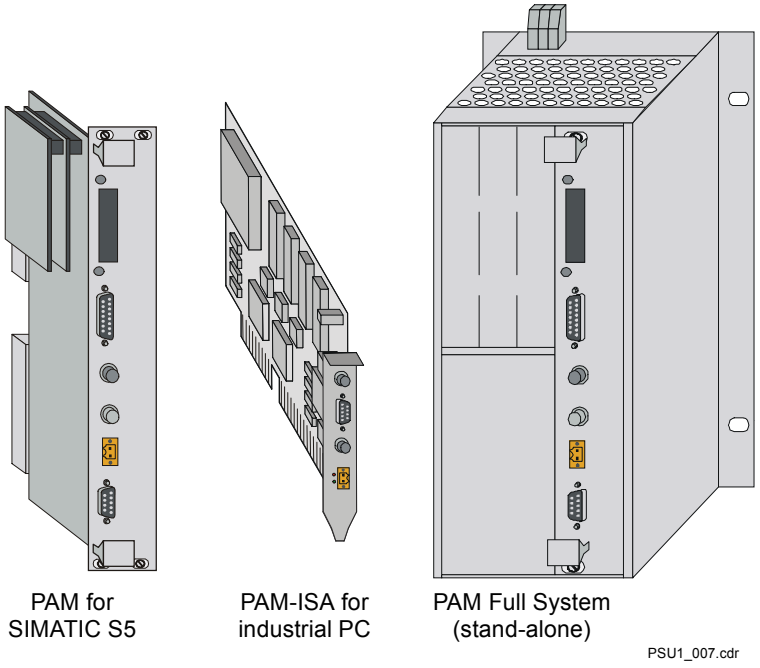


Figure 3 PAM with SAM System Components

Selecting and Ordering a PAM System

All PAM versions provide the same core functionality and an identical EasyBus interface.

Package Configuration	Host System or Upward Fieldbus	PAM Type	Ordering p/n
PC plug-in	ISA bus slot of an industrial PC	PAM-ISA board	9032 011 899
Simatic S5 plug-in	For a Simatic S5-115 system	PAM-S1N-H8F-AP-P	9032 011 154
	For a Simatic S5-135 system	PAM-S3N-H8F-AP-P	9032 011 155
	For a Simatic S5-155 system	PAM-S5N-H8F-AP-P	9032 011 156
Stand-alone Rack	no interface	PAM F25 Full System	9032 011 774
		PAM F05 Full System	9032 011 776
	Profibus-DP	PAM F51 Full System	new type available1Q/01
	RS422	PAM F26 Full System	9032 011 775

Package Configuration	Host System or Upward Fieldbus	PAM Type	Ordering p/n
	CAN-CAL	PAM-F17 Full System	9032 011 773

Table 1 PAM Configurations and Intended Applications

PAM Accessories

PAM Supply

The PAM Full Systems are housed in a panel-mountable chassis, which requires a single 24 VDC power source, which may be the same as for the SAM units (refer to 24 VDC Supply and Interlocks, page 9). This supply shall satisfy the same requirements as for a PLC, according to IEC/EN 61131-2 international standard.

The PAM-ISA board and PAM-P modules are housed in an industrial PC, respectively in a Simatic S5 PLC. They do not need any specific supply.

PAM Connectors and Cables

"Fatal Error" mating plug

The PAM-ISA board and PAM-F51 Full System (with Profibus) are fitted with a "Fatal Error" output, which requires one mating plug (X8). This plug is shipped together with the PAM unit. It is also described in Appendix A.

Communication-related cables and plugs

Depending upon their communication configuration, PAM Full Systems require communication cables in addition, i.e. according to Profibus-DP standard. We recommend using the same cable / mating plug supplier as for the other peripherals that are connected to this fieldbus. Please contact an ACC Motion Applications Center for any assistance if required.

EasyBus Connections

General

The EasyBus is constructed of fiber optic cables that link a PAM and all SAM Drives in a closed ring (see Figure 4). Three types of EasyBus cable assemblies are available including:

- Standard duty plastic fiber cables
- Kevlar reinforced plastic fiber cables
- Long distance fiber cables

The order in which each SAM Drive is placed within the EasyBus ring has no influence as far as functionality is concerned. For this reason it may be defined in a way that the total ring length is at the shortest, as it will reduce the overall fiber optic cable cost.

Exception: As the SAM Drives that are placed immediately downstream of PAM get thus a higher priority for transmitting events. This may have some importance in time-critical event-handling when the number of axes is larger than 6.

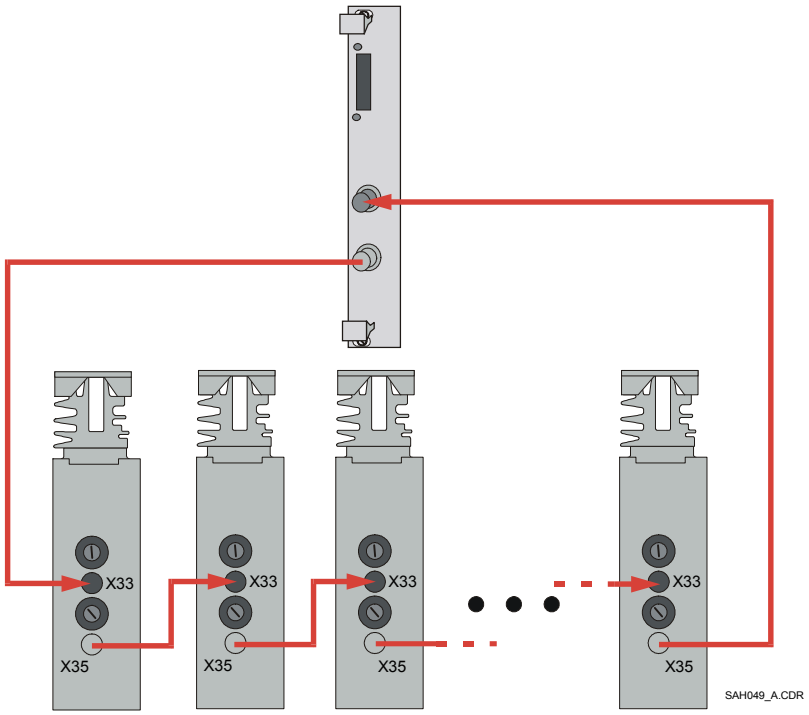


Figure 4 EasyBus Cables Link a PAM and SAM Drives in a Closed Ring

Selecting and Ordering EasyBus Cables

The total number of EasyBus cables required for a PAM with SAM system equals the number of SAM Drives in the system + 1.

When estimating the length of EasyBus cable segments, allow sufficient length for cable bends so the minimum bend radius specified in Table 3 is not exceeded.

Table 2 shows the properties and selection criteria for all fiber optic cables available.

Required length	Standard duty plastic fiber cables	Kevlar reinforced plastic fiber cables	Long distance fiber cables
0.3 m	9032 010 776		
0.5 m	9032 011 091		
1.0 m	9032 011 086		
2.0 m	9032 011 087	9032 011 092	
3.0 m	9032 011 056	9032 011 093	
5.0 m	9032 011 088	9032 011 094	
10 m	9032 010 774	9032 011 095	
15 m		9032 011 096	
20 m	9032 010 775	9032 010 777	
25 m			9032 010 778
50 m			9032 010 779
100 m			9032 011 100

Table 2 EasyBus Cable Ordering part numbers

Under no circumstance should a fiber optic cable be bent below its minimum bending radius, be it temporarily during assembly or definitively, as its light transmission capability would be severely decreased. Fiber optic cable may get accidentally bent while pulling out electric cables, if they are routed together within the same cable channels.

The PAM and SAM System provides for a fiber optic cable test routine, which helps detecting damaged sections and connectors. This routine can be initiated i.e. during machine maintenance. The light emission power of all units shall then be reduced to 80%. Any transmission capability reduction due to i.e. damaged cable will then be detected and signalized, so that the cable section can be replaced. This feature is especially helpful in case of spurious communication break-down. Upon test completion the light emission power is brought back to 100%.

EasyBus Cable Technical Data

	Standard duty plastic fiber cables	Kevlar reinforced plastic fiber cables	Long distance fiber cables
Intended applications	Interconnecting PAM & SAM Drives within an enclosure	Use when cables are run in cable trays or conduits along with other cables	Low loss cable for systems where the PAM & SAM Drives are widely spaced. This cable is not reinforced and must be protected from abuse.
Cable Temperature range	-20 to +80 °C	**-5 to +70 °C**	-20 to +80 °C
Minimum bending radius	50 mm	50 mm	50 mm
Cable diameter	2.2 mm	5.0 mm	5.0 mm
Tensile strength	**10 N**	150 N (50 N at plug level)	150 N (50 N at plug level)
Lengths of standard cable assemblies	**0.3 to 20 m**	**2.0 to 20 m**	**25 to 100 m**

Table 3 EasyBus Cable Properties and Selection criteria

Fiber-to-Fiber Optical Coupler

If required any fiber optic cable segment can be split in 2 parts, which are connected together using a Fiber-to-Fiber Optical Coupler. This may be useful if the various PAM and SAM units are housed in different cabinets, which must be disconnected i.e. for shipment.

This Fiber-to-Fiber Optical Coupler can be ordered as part number 9032 011 148.

Inserting one or two Fiber-to-Fiber Optical Coupler into an EasyBus segment (that is between 2 units) restrict the cable length as follow:

– If 1 Fiber-to-Fiber Optical Coupler is used:
  The Total length is limited to 16 meters
  (Example: 15-meter + 1 coupler + 1-meter segment)

– If 2 Fiber-to-Fiber Optical Couplers are used:
  The Total length is limited to 12 meters
  (Example: 1-meter + 1 coupler + 10-meter + 1 coupler + 1-meter segment)

It is not allowed to couple long distance cable with standard nor with Kevlar reinforced types.

AC Supply and Earthing

About International AC Supply Voltage Standards

The IEC 60038 standard specifies three-phase AC supply voltages around the world. At this time, in Europe, as well as many other countries, the nominal three-phase “low voltage” AC supply voltage is 400 VAC; (the older 380 and 415 VAC mains have been phased out). In North America, four standard three-phase AC supply voltages, 208, 240, 460 and 480 VAC, are in common use. A few other AC supply voltages are used in other countries. SAM is compatible with most standard AC Supply voltages as listed in Table 4.

SAM is also compatible with both 50 Hz and 60 Hz standard main frequencies.

Three Phase AC Supply		Geographical Area	Remarks
Nominal (VAC)	Range (VAC)		
208	187 - 229	North America	Use a step-up transformer, or reduce maximum motor speed
240	216 - 264	North America	Use a step-up transformer, or reduce maximum motor speed
380	342 - 418	Europe (phased-out)	Slight reduction in maximum motor speed
400	360 - 440	Europe	
415	373 - 440	UK (phased-out)	
460	437 - 529	North America	Automatic 10 % current derating
480	432 - 528	North America	Automatic 10 % current derating

Table 4 Standard AC Supply Voltages that are compatible with SAM

Selecting SAM Units that fit to AC Supply

SAM Drive Units

A single family of SAM Drives is compatible with operation from with any standard voltage listed in Table 4, including 480 VAC. The “400” that appears in their ordering key (i.e. SAM-DA-400-07N-P4N-E) has actually no meaning.

SAM Supply Units

Two families of SAM Units are available:

SAM-PA-400-…

These units fit to all standard voltages listed in Table 4, up to and including 415 VAC. They may operate up to 447 VAC peak voltage.

Above this supply voltage the DB Resistor gets continuously activated, which in turn activates the units “Fatal Error” output for disconnecting the power supply. Higher voltages may damage the equipment.

SAM-PA-480-…

These units fit to the 460 and 480 VAC standard voltages. They may operate up to 530 VAC peak voltage.

Above this supply voltage the DB Resistor gets continuously activated, which in turn activates the units “Fatal Error” output for disconnecting the power supply. Higher voltages may damage the equipment.

Using SAM at higher voltages

If the AC Supply voltage exceeds the maximum value listed in Table 4, a transformer must be used to reduce the voltage applied to the SAM Supply to within allowable limits (see "Optional Transformer" on page57).

Using SAM at lower voltages

A SAM System can be operated at low AC Supply voltages (theoretically down to zero volts). Machine designers must be aware that while braking the voltage applied to the motor increases slightly over SAM Supply Unit rated voltage.

All motors used with PAM and SAM System must have all isolations designed for the rated voltage of the SAM Supply unit that is chosen.

- 400 VAC when SAM-PA-400-… is used,
- 480 VAC when SAM-PA-480-… is used.

Motors that are designed for 240 VAC supplies should never be used. Otherwise isolation faults may occur while braking, and machine CE compliance cannot be achieved. Using a step-down transformer does not bring any improvement.

Single Phase and DC Supplies

Using a single-phase or DC supply is possible, but is beyond this document’s scope. For assistance in using PAM and SAM products in these circumstances, please contact an ACC Motion Applications Center and discuss your requirements with a motion specialist.

Accommodating Multiple AC Supply Voltages

A system/machine builder designing systems for international use must decide how to accommodate different AC supply voltage standards for the whole machine as well as for the power drive system. This decision normally considers the logistics cost for supporting a separate equipment configuration for each AC supply voltage verses the cost of adding a transformer to standardize the supply voltage internally.

A trade-off study evaluating utilization of a transformer for AC Supply Voltage standardization should not neglect the following facts:

In favor of using a transformer

- SAM Power Drive systems do not require isolation from the AC Supply; therefore, a lower cost auto-transformer may be used.

– Transformers are highly reliable and virtually maintenance free.

Against the use of a transformer

– The electrical efficiency of three phase auto-transformers is typically 98%. It means that 2% of its rated power shall be transformed into heat within the cabinet, even when not actually loaded.
– A transformer increases the voltage fluctuations at the drive system input. This may force using motors with lower K_t factor for reaching the speed goals. As a consequence higher motor current shall be needed, which may required a more powerful, and thus more expansive drive.

Earthing Requirements

Four Wire System with Solidly Earthed Neutral

The AC Supply **must** have a solidly earthed neutral, as all SAM units have been designed for overvoltage category III (EN50178).

If a three phaseAC Supply with solidly earthed neutral is not available, an isolation transformer with “Wye” connected secondary solidly connected to earth must be used (see "Optional Transformer" on page57).

Operating a PAM with SAM system is **prohibited** with following earthing methods:
– isolated (or floating) supply,
– resistance earthed neutral,
– solidly earthed line

For additional information on AC Supply earthing, refer to IEC 664-1: 1992-10, Table B2, column “Three phase, four wire systems with earthed neutral”, line "300 VAC line-to-neutral".

Motors

Motor Technology Choices

As a universal Drive System, PAM with SAM supports both AC servomotors (also called permanent magnet synchronous motors or DC-brushless servomotors) and induction motors (also called asynchronous motors). In both cases motors should be equipped with a position feedback device for closed-loop positioning operation.

SAM supports also linear and direct drive motors.

For assistance in using induction, linear and direct drive motors, please contact an ACC Motion Applications Center and discuss your requirements with a motion specialist.

Motor Selection

We provide standard, permanent magnet synchronous motors that have been designed and are specified for operation together with SAM drives.

Selection Procedure

Motor selection is often an iterative process, which begins with selection of a motor that satisfies the machine load requirements, followed by recalculation of the load with the motor's inertial contribution to the axis load considered. The procedure illustrated in Figure 5 is optimized for selection of a motor, which meets the axis load requirements at the lowest axis cost. If there are other constraints, such as motor physical size, motor type standardization, etc., these additional constraints must be taking into account during the motor selection process.

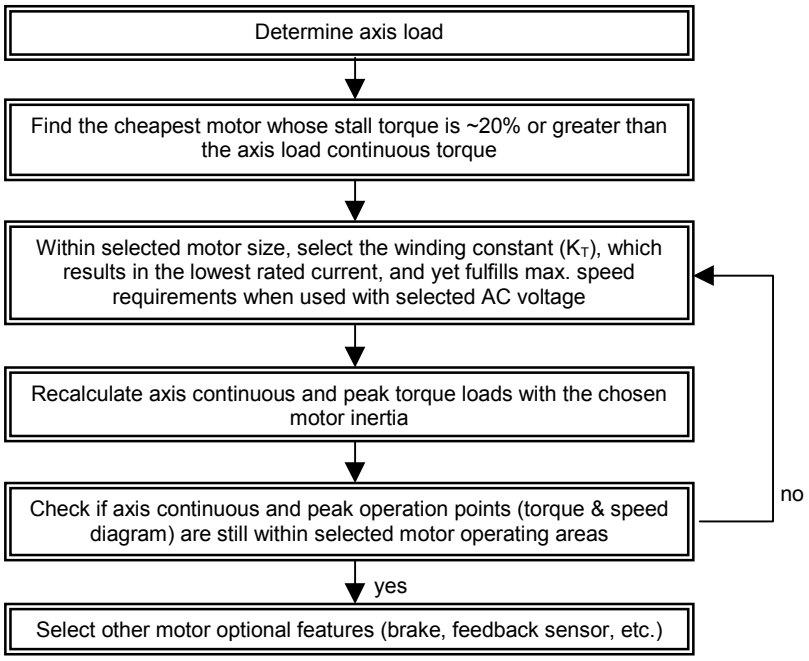

Determine axis load
Find the cheapest motor whose stall torque is ~20% or greater than the axis load continuous torque
Within selected motor size, select the winding constant (K_T), which results in the lowest rated current, and yet fulfills max. speed requirements when used with selected AC voltage
Recalculate axis continuous and peak torque loads with the chosen motor inertia
Check if axis continuous and peak operation points (torque & speed diagram) are still within selected motor operating areas
no
yes
Select other motor optional features (brake, feedback sensor, etc.)

Figure 5 Motor Selection Procedure

Figure 6 shows an example of characteristic curves for a motor. Four torque-speed curves with different style dashed and solid lines (also labeled 480V, 400V, 240V, and 208V in the figure) define the torque verses speed operating limits of a given motor in a SAM system, for each of these four AC Supply voltages. Note that these curves include compensation for AC Supply voltage at its low tolerance limit (nominal - 10%) and for SAM System internal voltage drops. The dashed curve labeled “Current” indicates the current verses torque characteristic of the motor. Current must always be read from the current scale (right-hand vertical scale in the figure).

The axis load continuous operation point must lie within the “Continuous operation area”. In a similar way peak load operation points must lie within the “Peak operation area”. As an example, both areas are shown in Figure 6 considering a 400 VAC supply voltage.

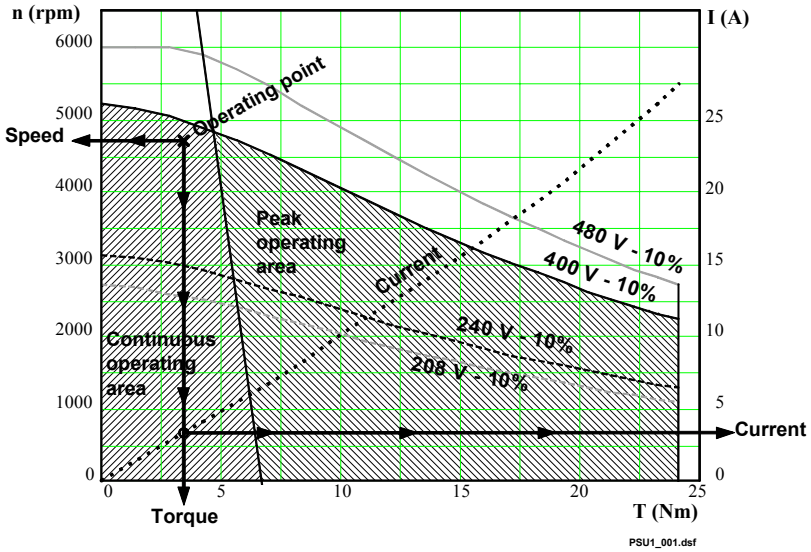


Figure 6 Reading Motors Characteristic Curves

Special Purpose Motors

Induction Motors

In some applications an induction (asynchronous) motor is required, as for winding / unwinding applications. Its major benefit is its "constant power" characteristics.

Example:

A motor must be able to deliver 12 Nm at 1500 rpm (bobbin is full) as well as at 3 Nm at 6000 rpm (bobbin is empty), that means at 1.9 kW shaft power. A permanent-magnet servomotor should be selected for achieving 12 Nm and 6000 rpm simultaneously, that means 7.6 kW shaft power. An induction motor instead, can be selected exactly for this 1.9 kW shaft power. Using field-weakening technique, it will be able to provide both high torque at low speed and low torque at high speed. The major saving is at the Drive level, as a much smaller one can be selected.

Linear Motors

Traditional linear motion solutions such as belt or rack and pinion increasingly fail to satisfy the highest accuracy, stiffness and bandwidth requirements. The linear motor is a direct drive solution that is readily interfaced to a PAM with SAM system and operated very much like a standard AC Servomotor. Linear motor/SAM Drive combinations, along with an appropriate linear feedback device achieve up to 10,000 N force, 20 m/s velocity, 300 m/s^2 (30 g) acceleration together with sub-micron accuracy.

Direct Drive Motors

Direct drive motors provide high torque with high stiffness for critical applications where the standard motor/reducer combination is insufficient. When combined with a high resolution feedback device (such as a sine-cosine encoder), the direct drive motor can satisfy the most demanding applications requiring high torque with high accuracy.

Applications Assistance

ACC Motion has assisted machine manufacturers in a variety of linear and direct drive projects. Our mechatronic experts can provide assistance in selecting the appropriate technology and in choosing the appropriate motor/feedback for the application.

Position Feedback Devices

Position Feedback Device Types and Characteristics

Resolvers

Using a simple analogy, a resolver is nothing more than a transformer with a rotating primary and two stationary secondary windings separated radially by 90 degrees. The primary winding, excited with a low power signal of several kilohertz, induces a voltages into each secondary winding. The signal amplitude in the secondary windings is a function of their angular relationship to the primary.

Conversion hardware/software in the SAM Drive determines the resolver's angular position from the ratio of signal amplitudes on the secondary windings (see Figure 7). Resolvers are inherently absolute position devices over one rotation.

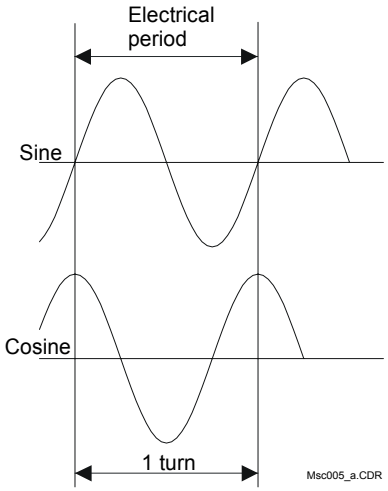


Figure 7 Resolver Output amplitude as a function of angle

Resolvers are widely used for position measurement in motion control systems. They offer the benefits of low cost, sturdiness, high reliability, wide dynamic range, good electrical noise immunity and absolute position readout over one revolution. They are passive devices; that is no active electronic components reside within the resolver. Table 5 summarizes the important characteristics of a typical resolver when used with a SAM Drive.

Accuracy	± 6 arc-min (limited by the resolver used)	
Resolution	7 arc-sec ≈ 200,000 counts/turn (limited by SAM Drive conversion process)	
Max. Speed	8,000 RPM	
Absolute position	Absolute over 1 turn	
Typical use	AC servomotors	yes
	Direct drive motors	no
	Linear motors	no
Relative cost	low	
Robustness	very high (no silicon, no glass)	
Typical applications	Any servo applications requiring high dynamic accuracy (pick and place, profiled motions): – Packaging – Handling	
Start-up	No motor movement (the motor magnetic angle is given by the resolver information)	

Table 5 Resolver Characteristics Summary

Most servomotor manufacturers offer an integral resolver as a standard motor option. Although most resolvers operate on the same physical principles and show similar electrical characteristics (i.e. impedance, transformation ratio, and excitation requirements), their real accuracy vary widely from model to model. Critical effects are:

- Speed accuracy: Even if the angle error lies within specification (i.e. ± 6 arc-min), its derivative is sometimes to high due to notch effects. This reduces tremendously the possible control gain that can be achieved, and thus the axis accuracy.
- Mounting error effects: The resolver rotor position toward its stator relies only on the motor flange and bearing accuracy. It may slightly change radially and axially by a few tenth of a millimeter, depending upon load, temperature, and aging. Only few resolver manufactures are able to keep the resolver's position and speed accuracy within specifications in such conditions.

We have carefully assessed resolvers used within motor ranges, so that best positioning accuracy can be achieved. Refer to Table 9.

Incremental Digital Encoders and Rulers

Incremental digital encoders and rulers are simple optical encoders that typically produce 1, 2 or 4 pulses per electrical period as illustrated in Figure 8. Most incremental encoders also provide a once/rev reference pulse. Although they can be interfaced to SAM Drives, incremental digital encoders and rulers are not recommended for a high-performance drive system. Servo loop stiffness is largely dependent on the resolution of the speed feedback signal and this is difficult to extract at very low speed from a few pulses and within a reasonable sampling interval.

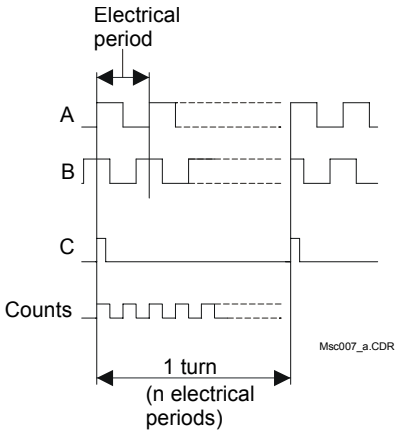


Figure 8 Incremental Digital Encoder Output

Incremental Sine-Cosine Encoders and Rulers

Incremental sine-cosine encoders and rulers are a recent development in the evolution of incremental optical encoders. Most versions produces two 90 degree shifted, differential 1V peak to peak signals called the sine and cosine outputs (because of their quasi-sinusoidal relationship to angle), plus a once/rev reference pulse (see Figure 9). These encoders and rulers have a bandwidth of 150 to 300 kHz. Incremental sine-cosine rulers are the only choice for linear motor applications. Table 6 summarizes typical performance characteristics for these encoders when used with SAM Drives. Performances for rulers can be estimated by converting angles into sine periods, and then into millimeters or microns.

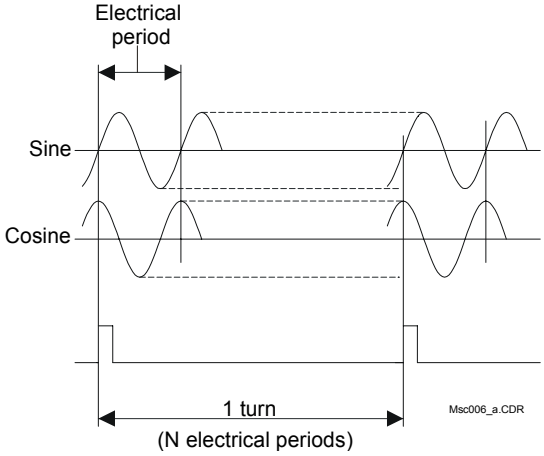


Figure 9 Incremental Sine-Cosine Encoder Output

The 1 Vpp signal quality is somewhat variable between encoder / ruler models and is frequently the limiting factor for servo stiffness. For bearingless models, the 1 Vpp signal quality is also sensitive to mechanical misalignment. Encoder / ruler manufacturers seldom specify signal quality.

Incremental sine-cosine encoders and rulers, being simple incremental devices, do not inherently provide sufficient information for a SAM Drive to determine the magnetic angle of synchronous motors (AC servomotors) at startup. To establish the motor's magnetic angle, the SAM Drive must create current vectors of small amplitude at different angles while observing behavior of the rotor until the

magnetic angle is determined. There are two ways of determining this magnetic angle at machine start-up:
If the application tolerate a series of small motor movements during initialization, then no additional hardware is required as SAM drives provide for a magnetic angle learning function. Such small movements usually reach a few sine periods, but may reach exceptionally up to half a pole angle / distance (i.e. 60 degrees for a 6-pole motor).
In the other case, or if the motor is hold by a brake when the drive is not active, then a more sophisticated encoder is required, which provides for single-turn absolute value in addition. Refer to the sections "Incremental Sine-Cosine Encoder with Commutation Track" and " Multiturn Absolute Sine-Cosine Encoder" below.

Accuracy	32 arc-sec (for a typical 2048 period encoder)	
Resolution	0.43 arc-sec ≈ 3,000,000 counts/turn (resolution of SAM Drive conversion process is 1/4900 of an electrical period)	
Max. Speed	4400 RPM (2048 period encoder with 150 kHz bandwidth; SAM Drive bandwidth is 450 kHz)	
Absolute position	no	
Typical use	AC servomotors	option
	Direct drive motors	option
	Linear motors	yes
Relative cost	high	
Robustness	good (limited by glass disk and silicon)	
Typical applications	Axes requiring high servo stiffness, or high accuracy at constant speed: – Printing applications	
Start-up	Some fractional turn motor shaft movement is required at startup to determine the motor's magnetic angle.	

Table 6 Incremental Sine-Cosine Encoder Characteristics Summary

Incremental Sine-Cosine Encoders and Rulers with Commutation Track

This is a special version of the incremental sine-cosine encoder that provides standard sine-cosine encoder outputs along with a second low resolution (one period/turn) sine-cosine output (see Figure 10). The SAM Drive utilizes this coarse sine-cosine output to establish the motor's magnetic angle at startup, thereby eliminating the necessity for a series of motor movements. All other characteristics are the same as for the incremental sine-cosine encoder (see Table 6).

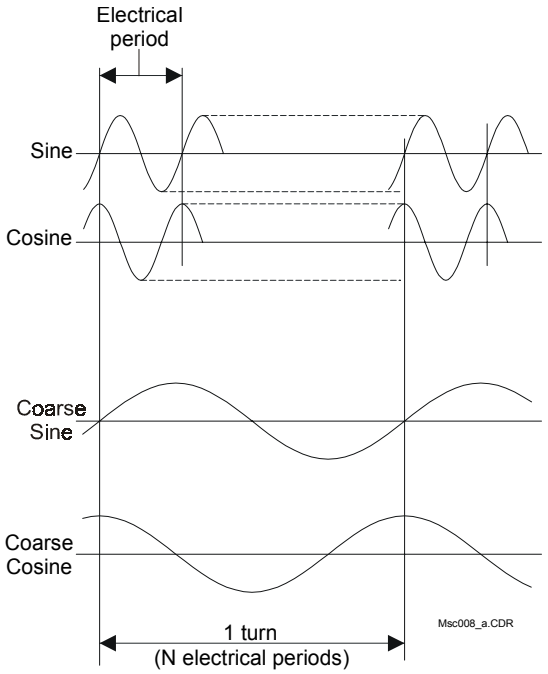


Figure 10 Incremental Sine-Cosine Encoder with Commutation Track

Multiturn Absolute Sine-Cosine Encoders and Absolute Sine-Cosine Rulers

The multiturn absolute sine-cosine encoder combines the characteristics of a standard sine-cosine encoder with the capability for absolute position readout over 4096 turns. These devices are typically used in applications where the orientation of an axis load not coupled 1:1 to the axis motor must be directly measurable on demand.

The multiturn absolute sine-cosine encoder provides standard sine/cosine encoder outputs for motor commutation and servo loop closure. On demand (typically at startup) the multiturn encoder sends data words containing the motor's offset (number of turns from a pre-defined home reference position) and angle (the angular position within a turn, generally with accuracy better than ½ an electrical period). This information permits the SAM Drive to establish the axis absolute position and motor's magnetic angle. The offset and angle data are transmitted over a separate serial communications line using a communications protocol such as ENDAT.

Multiturn absolute sine-cosine encoders are available for rotary applications. Absolute sine-cosine rulers for linear applications with similar functionality are also available, and use the same protocol. Table 7 summarizes the typical performance characteristics for a multiturn encoder when used with a SAM Drive. Performances for rulers can be estimated by converting angles into sine periods, and then into millimeters or microns.

Accuracy	32 arc-sec (for a typical 2048 period encoder)	
Resolution	0.43 arc-sec ≈ 3,000,000 counts/turn (resolution of SAM Drive conversion process is 1/4900 of an electrical period)	
Max. Speed	4400 RPM (2048 period encoder with 150 kHz bandwidth; SAM Drive bandwidth is 450 kHz)	
Absolute position	Yes, typically over 4096 turns	
Typical use	AC servomotors	option
	Direct drive motors	option
	Linear motors	yes
Relative cost	very high	
Robustness	good (limited by glass disk and silicon)	
Typical applications	Axes requiring high servo stiffness, or high accuracy at constant speed, and direct readout of axis absolute position at startup: – Printing applications	
Start-up	No motor movement (the motor magnetic angle is given together with the multiturn information)	

Table 7 Mutli-turn Absolute Sine-Cosine Encoder Characteristics Summary

Single Turn Absolute Sine-Cosine Encoders

This is a less expensive version of the multiturn absolute sine-cosine encoder that provides standard sine-cosine encoder outputs along with angle readout (over an ENDAT serial communications channel) for establishing the motor's magnetic angle and absolute position over one turn. All other characteristics are the same as listed in Table 7.

Multiturn Resolvers

The multiturn resolver is functionally similar to the multiturn absolute sine-cosine encoder with the exception that it provides standard resolver outputs for motor commutation and servo loop closure along with absolute position readout over 4096 turns. This is the most appropriate multiturn absolute sensor for packaging and handling applications, thanks to its lowest price and its very high robustness (>50,000 hours of operation at 125 °C).

Multiturn resolvers are available for rotary applications only. Table 8 summarizes the performance characteristics for a multiturn resolver in combination with a SAM Drive.

Accuracy	± 6 arc-min (limited by the resolver used)	
Resolution	7 arc-sec ≈ 200,000 counts/turn (limited by SAM Drive conversion process)	
Max. Speed	8000 RPM	
Absolute position	Yes, over 4096 turns	
Typical use	AC servomotors	option
	Direct drive motors	option
	Linear motors	no
Relative cost	moderate	
Robustness	very good (no glass disk)	
Typical applications	Any servo applications requiring high dynamic accuracy, and direct readout of axis absolute position at startup: – Pick and place – Profiled motions – Packaging and handling	
Start-up	No motor movement (the motor magnetic angle is given together with the multiturn information)	

Table 8 Multiturn Resolver Characteristics Summary

Using a 2nd Position Feedback Device

Axes Requiring Two Feedback Devices

Two feedback devices are required for applications such direct product position tracking. A SAM Drive can support two feedback devices; however, there are some restrictions on feedback devices combinations. When designing such applications, refer to Table 12, which lists all possible feedback device combinations supported by the SAM Drive.

Master Slave Applications

The resolver/encoder connected to the remote apparatus in master/slave tracking applications can be interfaced to the second position feedback port of a SAM Drive. Any type of supported feedback device may be used for remote master tracking; however, there are some restrictions on combinations of feedback devices that can be interfaced to a SAM Drive. When designing such applications, refer to Table 12, which lists all possible feedback device combinations supported by the SAM Drive.

Selecting Compatible Feedback Devices

When selecting feedback devices, refer to Table 9 and Table 10, which list compatible feedback devices for the SAM Drive, which have been assessed for use (and in many cases tested) with the SAM Drive.

Rotary Device type	tested	Manufacturer & type
Resolvers – open frame	YES YES YES YES YES	LTN RE-21-1-A04 LTN RE-15-1-A14 SAGEM 21RX 39 02 11 SAGEM 15RX 39 01 30 HAROWE 21BRCX-607-HG72A
Resolvers – housed	YES	LTN R58WVRE151A14-031-07CX
Incremental sine-cosine encoders	YES YES YES YES YES	Heidenhain ROD486-2048 Heidenhain ERN 480-2048 Heidenhain ERM 180 – 2048 (magnetic, hollow shaft) Heidenhain ERN 180-5000 Heidenhain RON287 – 18000 (2.5” accuracy)
Incremental sine-cosine encoders, with add. sine-cosine commutation track	YES YES NO NO	Heidenhain ERN1387-2048 Hübner HOGS60 DN 1024 Hengstler S21 Tamagawa OIH35
Multiturn absolute sine-cosine encoders	YES NO	Heidenhain EQN1325 (4096 turns - EnDat) Hübner AMG10E512R
Single turn absolute sine-cosine encoders	NO	Heidenhain ECN 1313 (1 turn - EnDat)
Multiturn resolvers	YES	LTN MT-21-1-A05 (4096 turns - EnDat)

Table 9 SAM-Compatible Rotary Feedback Devices

Linear Device type	tested	Manufacturer & type
Sine-cosine ruler	YES YES YES	AMO PMK-01-V (coarse, magnetic,1mm période) Zeiss LIE-5 1P COFA Heidenhain LIDA 187, LIDA 181
Absolute sine-cosine rulers	NO	Heidenhain LC181 (EnDat)

Table 10 SAM-Compatible Linear Feedback Devices

Incremental encoders and rulers are manufactured with very different characteristics such as measurement principle (optical, magnetic), accuracy (1 arc-min to 1 arc-sec), mechanical mounting, etc. All incremental encoders and rulers meeting both of the following conditions can be used with the SAM Drive:

- 1Vpp sine-cosine voltage outputs.
- Less than 250 mA consumption from the 5VDC supply.

SAM Drives

Introduction

Procedure for selecting SAM Drives

Since a Power Drive system usually includes multiple axes, the system designer must select the appropriate model SAM Drive for each axis, considering the motor, load torque and options required on an axis by axis basis. Proceeding according to the system component selection procedure (see Figure 1), load conditions for each axis in terms of velocity and torque have been defined. Motors and feedback devices have been selected. Figure 11 illustrates the steps in selecting a SAM Drive and accessories. Proceed sequentially through the tasks listed in Figure 11, branching where indicated, to the referenced pages for the details.

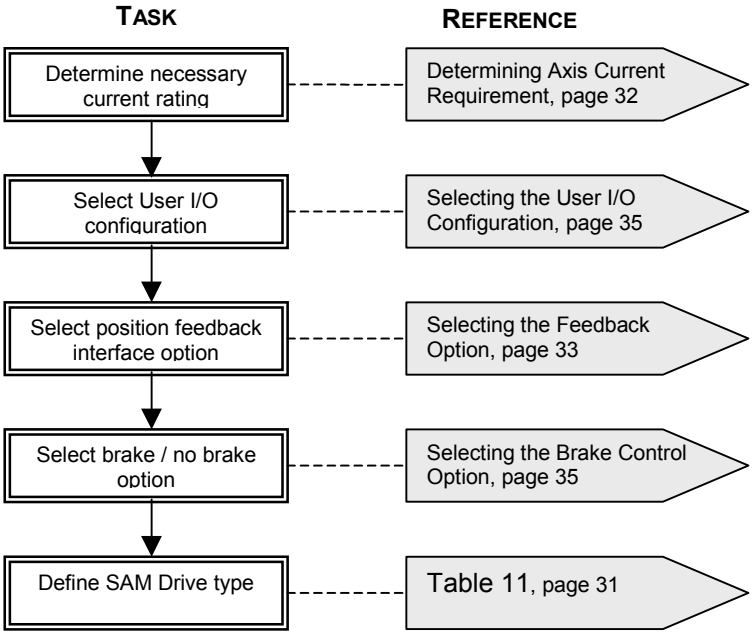

TASK
REFERENCE
Determine necessary current rating
Determining Axis Current Requirement, page 32
Select User I/O configuration
Selecting the User I/O Configuration, page 35
Select position feedback interface option
Selecting the Feedback Option, page 33
Select brake / no brake option
Selecting the Brake Control Option, page 35
Define SAM Drive type
Table 11, page 31

Figure 11 General Procedure for Selecting a SAM Drive

Drive Selection Strategy

This procedure results in selection (for each axis) of the lowest cost SAM Drive which will “do the job”. In some circumstances, when one considers the cost of carrying a spares inventory which includes several models of SAM Drives, the lowest total cost solution may be to select for all axes the lowest cost SAM Drive which satisfies the requirements for all axis. This is a perfectly acceptable strategy since the user may constrain each SAM Drive to operate within the operating limits of the motor.

Ordering Information

SAM Drives (including options and accessories) are determined by part number or by model number. Figure 12 illustrates the construction of a SAM Drive's model number based on its current rating and included options. The SAM Drive options

described in this section are not field-installable. They must be installed at the factory. Once the model number is determined, locate the part number for selected SAM Drive model in Table 11.

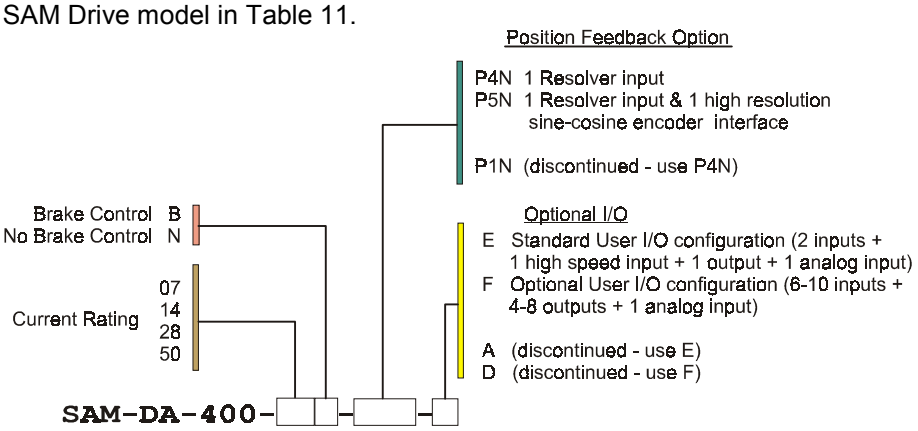

Position Feedback Option
P4N 1 Resolver input
P5N 1 Resolver input & 1 high resolution sine-cosine encoder interface
P1N (discontinued - use P4N)
Optional I/O
E Standard User I/O configuration (2 inputs + 1 high speed input + 1 output + 1 analog input)
F Optional User I/O configuration (6-10 inputs + 4-8 outputs + 1 analog input)
A (discontinued - use E)
D (discontinued - use F)
Brake Control B
No Brake Control N
Current Rating
07
14
28
50
SAM-DA-400-

Figure 12 SAM Drive Model Numbering Key

Voltage supply used ↓	Switching frequency ↓		Output current rating ↓			
400 VAC →	8 kHz → (standard)	I_{cont} [A_{rms}]	8	15	28	58
		I_{peak} [A_{rms}]	13	34	49	84
	4 kHz → (optional)	I_{cont} [A_{rms}]	6.5	15	20	34
		I_{peak} [A_{rms}]	10	28	38	62
480 VAC →	8 kHz → (standard)	I_{cont} [A_{rms}]	7	15	24	56
		I_{peak} [A_{rms}]	12	33	46.5	79
	4 kHz → (optional)	I_{cont} [A_{rms}]	6	15	16.5	30
		I_{peak} [A_{rms}]	8	26	34.8	56
			SAM-DA-400-07… ↓	**SAM-DA-400-14…** ↓	**SAM-DA-400-28…** ↓	**SAM-DA-400-50…** ↓
feedback ↓	**I/Os** ↓	**brake output** ↓				
resolver →	3 inputs (1 fast) 1 output	yes →	**…B-P4N-E**	9032 010 552	9032 010 553	9032 010 554	9032 010 555
		no →	**…N-P4N-E**	9032 010 512			9032 010 515
	6 inputs, 4 outputs 4 bi-directional I/Os	yes →	**…B-P4N-F**	9032 010 562	9032 010 563	9032 010 564	9032 010 565
		no →	**…N-P4N-F**	9032 010 522			
resolver + encoder or → multiturn resolver	3 inputs (1 fast) 1 output	yes →	**…B-P5N-E**	9032 010 557	9032 010 558	9032 010 559	9032 010 560
		no →	**…N-P5N-E**	9032 010 517			
	6 inputs, 4 outputs 4 bi-directional I/Os	yes →	**…B-P5N-F**	9032 010 567	9032 010 568	9032 010 569	9032 010 570
		no →	**…N-P5N-F**	9032 010 527			

Table 11: SAM Drive selection and ordering information (large drives are available only with brake output option)

Example: SAM-DA-400-07N-P5N-E, with part number 9032 010 517, is a SAM Drive Unit with the following characteristics and options:

- 6.5 A_{rms}. continuous current and 10 A_{rms} peak current rating at 400 VAC and 8 kHz switching frequency
- interface for one resolver and one sine-cosine encoder feedback with ENDAT

- standard User I/O configuration (2 inputs, 1 fast input, 1 output)
- no brake control option

Determining Axis Current Requirement

General Information

The SAM Drive current requirement is calculated based on the axis (motor plus load) continuous and peak torque requirements determined during motor selection. These same torque values (T_{CONT} and T_{PEAK}) should be used for calculating the SAM Drive current requirements. The procedure follows.

i

SAM Drives have different output current ratings depending on PWM switching frequency selected. The nominal 8 kHz switching frequency provides a higher pass band and lower acoustic noise. A 4 kHz switching frequency with higher output current but slightly lower pass band and higher acoustic noise may be selected.

Continuous and Peak Current Calculation

1. Using the performance curves for the selected motor, locate the axis continuous torque value (T_{CONT}) on the horizontal axis. Draw a vertical line to the CURRENT curve, then read continuous motor current (I_{MCONT}) required from the right-hand vertical axis (see Figure 6). Multiply continuous motor current by 1.1 and record the value as I_{MCONT}. The continuous motor current must be multiplied by 1.1 to accommodate a +/- 10% tolerance in the motor torque constant.
2. In **Error! Reference source not found.**, locate the SAM Drive model whose continuous current rating (I_{CONT}) at the selected AC Supply Voltage (i.e. 480 or 400 VAC) is greater than the continuous motor current (I_{MCONT}) recorded in Step 1.

Peak Current Duration Calculation

3. Locate the axis peak torque value (T_{PEAK}) on the horizontal axis. Draw a vertical line to the CURRENT curve, then read peak motor current (I_{MPEAK}) required from the right-hand vertical axis (see Figure 6). Multiply peak motor current by 1.1 and record the value as I_{MPEAK}.
4. Verify that the peak motor current (I_{MPEAK}) recorded in Step 2 does not exceed I_{PEAK} for the selected SAM Drive. If the peak motor current requirement is greater that I_{PEAK}, a SAM Drive with higher current rating must be selected.
5. A SAM Drive can supply its peak rated current (I_{PEAK}) for at least two seconds before tripping due to thermal overload. A SAM Drive can supply lesser magnitude currents in excess of I_{CONT} for longer intervals in an I^2t relationship (approximately). Proceed as follows to verify the SAM Drive's capability to supply the axis peak current demand:
6. Compute I^2t for the SAM Drive selected in Step 2 above as follows:

   Compute $I^2t_{DRIVE} = (I_{PEAK})^2 * 2$
   where I_{PEAK} is the peak rated current of the selected SAM Drive.

   Compute $I^2t_{MOTOR} = (I_{MPEAK})^2 * t_{PEAK}$
   where I_{MPEAK} is the peak motor current (computed in step 3) and t_{PEAK} is the duration (in seconds) of I_{MPEAK}.

Verify that $I^2t_{DRIVE} > I^2t_{MOTOR}$,
if not, a SAM Drive with larger current rating must be selected.

Drive Selection Example

Consider the following situation:

- An AHR115-C6-64 motor has been selected
- Axis continuous torque is 3.5 Nm and max. required speed is 4500 RPM
- Axis peak torque requirement is 10.7 Nm for 2.1 seconds, and occurs once every 30 seconds
- AC Supply voltage is 400 VAC
- Selected drive to be operated at 8 kHz switching frequency

Using the above procedure and characteristic curves for the AHR115-C6-64 motor, the SAM Drive continuous and peak current requirements (after compensation for motor torque constant tolerance) are (see Figure 13):

- $I_{MCONT} = 5 * 1.1 = 5.5\ A_{rms}$
- $I_{MPEAK} = 15 * 1.1 = 16.5\ A_{rms}$

Based on the continuous current requirement, a SAM-DA-400-07 is a good fit; however it cannot supply the peak current required. The SAM-DA-400-14 can supply both the continuous and peak current required.

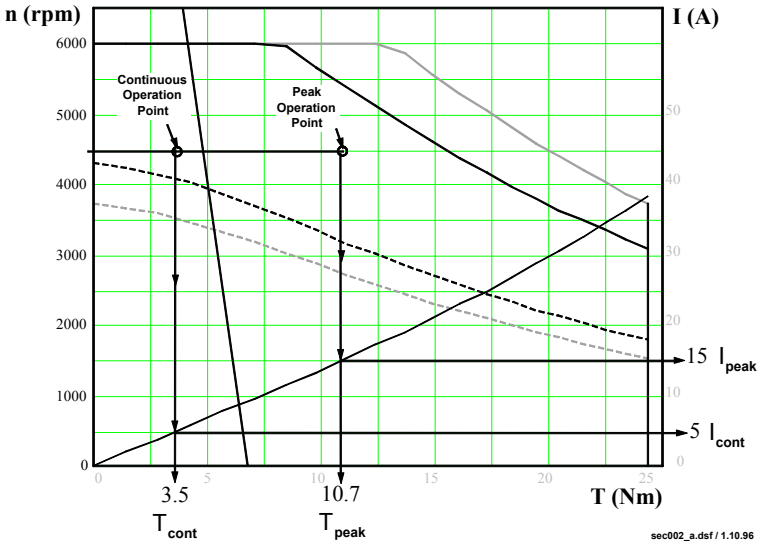


Figure 13 Continuous and Peak Current Requirements for Example

Evaluating the peak current duration requirement,

- $I^2t_{DRIVE} = (28)^2 * 2 = 1568\ A^2s$
- $I^2t_{MOTOR} = 16.5^2 * 2.1 = 572\ A^2s$

The selected SAM Drive can supply the peak current during the required time. Therefore, the SAM-D-400-14 satisfies the requirement totally and would be a correct choice.

Position Feedback Options

Selecting the Feedback Option

Select feedback option P4N or P5N based on the feedback device type(s) to be interfaced to the SAM Drive.

Resolver Input – Option P4N

This option (P4N) provides a single feedback port for interfacing a single resolver to the SAM Drive. Normally the resolver providing feedback from the axis motor is connected to this port. If the SAM Drive is not controlling a motor, this port may be used to interface a remote master resolver to the system.

Resolver plus Encoder – Option P5N

Option P5N provides two feedback ports for interfacing one or two feedback devices. One port is a standard resolver port. The second port is an encoder port with necessary hardware for interfacing the following feedback device types:
Incremental sine-cosine encoder / ruler with or without commutation track
single turn or multiturn absolute sine-cosine encoder, or sine-cosine ruler, with ENDAT serial interface
multiturn resolver with ENDAT serial interface (requires both ports)

The encoder / ruler port hardware includes a controlled 5 VDC supply with current and voltage sense lines. This feature enables encoders to be operated with cable lengths up to 100 meters.

Table 12 lists the devices and device combinations supported. In cases where two feedback devices are connected, there is no restriction concerning which port is connected to the feedback device on the axis motor, this assignment is made in software.

Config. #	Resolver port (X24)	Encoder port (X23)
1	Resolver	---
2	---	Incremental sine-cosine encoder, or ruler with/without commutation track
3	---	Single or multi turn absolute sine-cosine encoder, or absolute ruler, with ENDAT
4	Resolver	Incremental sine-cosine encoder, or ruler with/without commutation track
5	Resolver	Single or multi turn absolute sine-cosine encoder, or absolute ruler, with ENDAT
6	Multi turn resolver (requires both ports)	

Table 12 Feedback Devices and Combinations for Option P5N

Brake Control Option

The Brake output is used for controlling a 24 VDC electromechanical motor brake on motors so equipped. An external 24 VDC power source must be provided for powering the brake. The Brake output is compatible with most holding brakes available on motors.

The Brake ouput may also be used to operate a relay-based, dynamic braking circuit for the axis motor.

Applications for the Brake Control output are described in Part 3 - “Safety and Protective Functions”.

Selecting the Brake Control Option

If SAM Drive current rating is the lowest one (SAM-DA-400-07…), and if no brake control is required, than select "No Brake Control".

In all other cases select "With Brake Control" (it is a standard feature for all SAM Drives with larger current rating).

User I/O Options

Selecting the User I/O Configuration

A SAM Drive may be ordered with either a standard or expanded User I/O configuration for controlling machine functions. All Users I/O are electrically isolated with shared power and common connections. Refer to Part 2 - “System Design and Integration” for a functional description and to Part 5 - “SAM Drive Technical Information” for specifications.

Select either the standard or expanded User I/O configuration (See Table 13), depending on the types and quantity of User I/O needed.

	Standard Configuration SAM-DA-…-E	**Expanded I/O Configuration SAM-DA-…-F**
high speed digital input	1	0
digital input	2	6
digital output	1	4
bi-directional I/0	0	4
analog input	1	1

Table 13 Standard and Expanded User I/O configuration

High Speed Digital Input

The High Speed Digital Input is intended for use with high speed adaptive control functions (i.e. registration mark sensing in an automatic registration function) where minimum propagation delay and repeatability are required. The High Speed Digital Input is available only with the standard User I/O option.

Bi-directional I/Os

With the expanded I/O configuration, 4 bi-directional ports are user-programmable as either digital inputs or digital outputs.

When configured as an output, it can also be read as input. It is thus possible to connect several ouputs of several SAM drives together, and to use them as a “wired-OR” combination. This can be usefull when programming safety function

within the SAM drives, which should be active when the communication with PAM and the rest of the machine fail.

Analog Input

The analog Input is logically a part of the User I/O; however, physically its hardware components are located within the Position Feedback Interface.

It is a +/- 10 V PLC/CNC type differential analog input with 12 bit resolution. It is available for general use as a User input. Refer to Part 2 - “System Design and Integration” for a functional description and to Part 5 - “SAM Drive Technical Information” for specifications.

Mating Cables and Plugs for SAM Drives

General Information

PAM and SAM System cables and mating connectors are not systematically shipped with each SAM Drive, and must be ordered separately depending upon the user's cable supply strategy, which can be either of followings:

Using SAM System ready-made cables, DC-bus bar and connector kits.

Using only SAM System connector kits.

Acquiring all cables and connectors from a third party. In that case we recommends using the specified connector suppliers

This section describes only the product selections for the first supply strategy.

i

Users who decide purchasing cables, connectors, and wiring accessories from a third party, will find detailed cable and connector information in Appendix A - Mating Plugs Specifications and Appendix B - Cables.

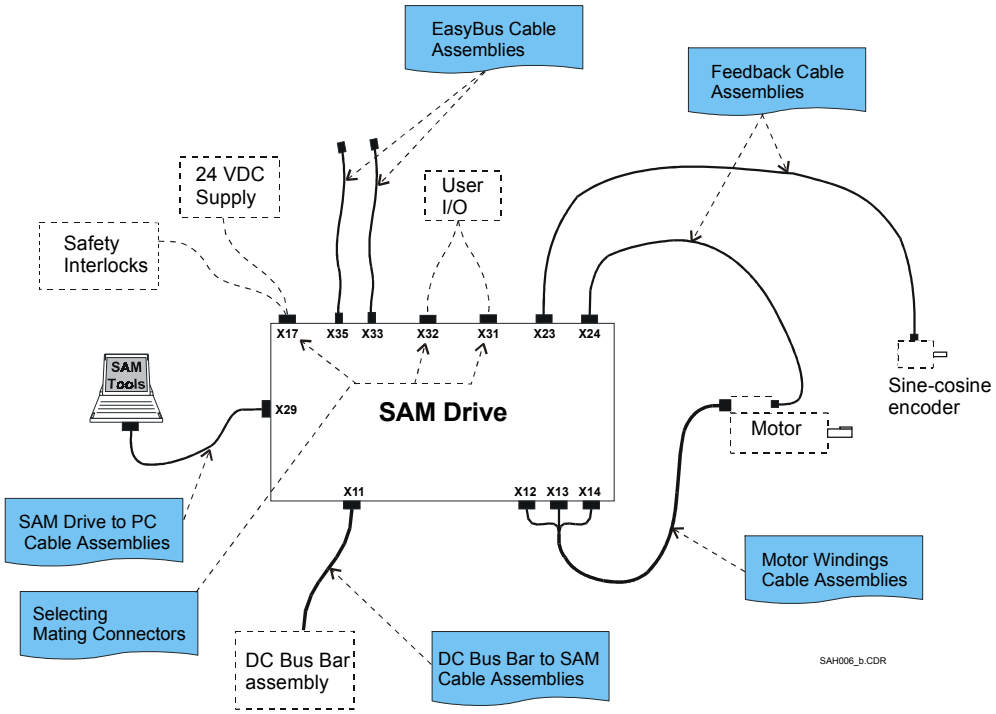


Figure 14 SAM Drive Cable Assemblies and Mating Connectors

Motor Windings Cable Assemblies

General Information

Motor Windings Cable assemblies are terminated on the motor end with the correct mating connector/strain relief for the designated motor. The other end is terminated in the correct mating connectors for the designated SAM Drive. Any length is available, up to 100 meter. These cable assemblies are tested and approved for use in stationary applications where the cable is not subject to repeated or continuous flexing. They are rated for use in systems operated at AC Supply voltages up to 480 VAC.

1st Selection Criteria: Windings Conductor Cross-section

According to IEC 60204-1 standard, the current carrying capacity for standard PVC cable depends upon following criteria:

- conductor cross-section
- number of cables that are routed within the same conduit
- maximum ambient temperature (if not 40 °C)

Table 14 and Table 15 reproduce IEC 60204-1 standard figures, and must be used for selecting the minimum cross-section required. Selecting a larger cross-section is allowed, and may help reducing the number of different cable types in some cases.

		↓ Cross-section ↓					
		1 mm²	**1.5 mm²**	**2.5 mm²**	**4 mm²**	**6 mm²**	**10 mm²**
→ **Nb. of cables in conduit** →	**1**	9.6 A_{rms}	12.2 A_{rms}	16.5 A_{rms}	23.0 A_{rms}	29.0 A_{rms}	40.0 A_{rms}
	2	7.7 A_{rms}	9.8 A_{rms}	13.2 A_{rms}	18.4 A_{rms}	23.2 A_{rms}	32.0 A_{rms}
	4	6.2 A_{rms}	7.9 A_{rms}	10.7 A_{rms}	15.0 A_{rms}	18.9 A_{rms}	26.0 A_{rms}
	6	5.5 A_{rms}	7.0 A_{rms}	9.4 A_{rms}	13.1 A_{rms}	16.5 A_{rms}	22.8 A_{rms}
	9	4.8 A_{rms}	6.1 A_{rms}	8.3 A_{rms}	11.5 A_{rms}	14.5 A_{rms}	20.0 A_{rms}

Table 14 Current carrying capacity for various conductor cross sections at 40 °C

ambient air temperature	multiply Table 14 current by
30 °C	1.15
35 °C	1.08
40 °C	1.00
45 °C	0.91
50 °C	0.82
55 °C	0.71
60 °C	0.58

Table 15 Correction factor as a function of ambient temperature

For applications not covered in this section, refer to IEC / EN 60204-1 standard.

2nd Selection Criteria: 8 or 4 Conductors

Two cable configurations are available including:
4 conductor cable (4 heavy motor current conductors with shield)
8 conductor cable (4 heavy motor current conductors with shield, plus two shielded pair of signal conductors for motor thermal protector and optional brake control).

If the axis uses either a Brake Control Option or motor-mounted thermal protector or both, the 8 conductor cable should be used. In Table 16, locate the article part number for cable needed, depending upon cross-section, motor and SAM drive types.

For axes not using the Brake Control Option nor motor-mounted thermal protector, the lower cost 4 conductor motor windings cables listed in Table 17 may be used.Winding Cables available and Ordering part numbers

Motor Cables available and Ordering part numbers

Motor Windings cable assemblies are ordered by part number based on:
- number of conductors (select Table 16 or Table 17)
- cross-section (select the appropriate column)
- motor and SAM drive combination (select the appropriate line)

Be aware that these part numbers are defined for 5-meter long cables. For other lengths, ask your SAM System supplier for the corresponding part number.

		↓ Cross-section ↓					
↓ motor range ↓	↓ SAM drive ↓	1 mm²	1.5 mm²	2.5 mm²	4 mm²	6 mm²	10 mm²
Bautz (plugs) SEM AHD55 SEM AHD70	SAM-DA-400-**07**x-… SAM-DA-400-**14**x-…	9032 011 114	9032 011 115				
SEM AHD92 SEM AHD115	SAM-DA-400-**07**x-… SAM-DA-400-**14**x-…	9032 011 116	9032 011 117	9032 011 118	9032 011 119		
	SAM-DA-400-**28**x-… SAM-DA-400-**50**x-…				9032 011 123		
SEM AHD142 SEM AHD190	SAM-DA-400-**07**x-… SAM-DA-400-**14**x-…		9032 011 120	9032 011 121	9032 011 122		
	SAM-DA-400-**28**x-… SAM-DA-400-**50**x-…				9032 011 125	9032 011 126	9032 011 127

Table 16 8-conductor Motor Windings Cable Selection and Ordering information

		↓ Cross-section ↓					
↓ motor range ↓	↓ SAM drive ↓	1 mm²	1.5 mm²	2.5 mm²	4 mm²	6 mm²	10 mm²
Bautz (plugs) SEM AHD55 SEM AHD70	SAM-DA-400-**07**x-… SAM-DA-400-**14**x-…		9032 011 943				
SEM AHD92 SEM AHD115	SAM-DA-400-**07**x-… SAM-DA-400-**14**x-…		9032 011 188	9032 011 189			
	SAM-DA-400-**28**x-… SAM-DA-400-**50**x-…					9032 011 195	
SEM AHD142 SEM AHD190	SAM-DA-400-**07**x-… SAM-DA-400-**14**x-…			9032 011 192	9032 011 193		
	SAM-DA-400-**28**x-… SAM-DA-400-**50**x-…					9032 011 197	9032 011 198

Table 17 4-conductor Motor Windings Cable Selection and Ordering information

Feedback Cable Assemblies

General Information

Feedback Cable assemblies are terminated on the motor end with the correct mating connector/strain relief for the designated motor. The other end is terminated with the correct mating connectors for SAM Drives. Any length is available, up to 100 meter. These cable assemblies are tested and approved for use in stationary applications where the cable is not subject to repeated or continuous flexing.

Feedback cable assemblies are available for all compatible types of position feedback devices including:
- Resolvers integral to AC servomotors
- Sine-cosine encoders integral to AC servomotors (with or without ENDAT link)
- Multiturn resolvers integral to AC servomotors

For cables to remote position feedback devices (i.e. a ruler, or an encoder that monitors a master-axis), ask your SAM System supplier.

1st Selection Criteria: Feedback Type

Three feedback cable configurations are available including:
- feedback cable for standard resolver integral to servomotor
- feedback cable for optional encoder integral to servomotor (with ENDAT link)
- feedback cable for optional multiturn resolver integral to servomotor

Feedback Cables available and Ordering part numbers

Feedback cable assemblies are ordered by part number based on:
- feedback type (select the appropriate column)
- motor type (select the appropriate line)

Be aware that these part numbers are defined for 5-meter long cables. For other lengths, ask your SAM System supplier for the corresponding part number.

	↓ Feedback type ↓		
↓ motor range ↓	Standard Resolver	Optional Encoder (with ENDAT link)	Optional Multiturn Resolver
Bautz (plugs) SEM AHD55 SEM AHD70	9032 010 742	ask supplier	ask supplier
SEM AHD92 SEM AHD115 SEM AHD142 SEM AHD190	9032 010 745	ask supplier	ask supplier

Table 18 Feedback Cable Selection and Ordering information (5 meter)

DC bus Cable Assemblies

General Information

The DC Bus distributes DC Power at high voltage and current levels from a SAM Supply to SAM Drives in a PAM with SAM system. Refer to DC-bus Bar, page 49

for further explanations. This section relates only to selecting the appropriate cable assemblies for connecting each SAM Drive to the DC bus Bar.

DC-bus bar Cables available and Ordering part numbers

Ready-made cable connections for each SAM Drive are following:

- P/n 9032 011 938: DC-bus bar to SAM-DA-07/14 cable, 3 x 4 mm^2, 400 mm
- P/n 9032 011 939: DC-bus bar to SAM-DA-28/50 cable, 3 x 6 mm^2, 400 mm

Note: SAM-DA-50 requires 2 cables in parallel when working with continuous full load @4kHz.

Selecting Mating Plugs

When SAM System Ready-made cables are used, only a few mating plugs must be ordered in addition, most of them depending upon SAM optional features.

Connector	Functions	Comments	Ordering p/n
X17	24 VDC supply & safety interlocks	Compulsory: One piece for every SAM Drive.	9032 010 696
X23	Encoder Feedback	Optional (SAM-DA-…-P5N-…): Only if additional encoder / ruler interface is used	9032 011 104
	User analog input	Optional (SAM-DA-…-P5N-…):: Only if analog input is used	9032 011 104
X24	Resolver Feedback	Optional (SAM-DA-…-P4N-…):: Only if additional resolver is used	9032 010 699
	User analog input	Optional (SAM-DA-…-P4N-…):: Only if analog input is used	9032 010 699
X31	User I/O	Optional (SAM-DA-…-E, 3 I/Os): Only if user's I/O are used	9032 011 072
X32	User I/O	Optional (SAM-DA-…-F, 14 I/Os): Only if user's I/O are used	9032 010 793
		Optional (SAM-DA-…-E, 3 I/Os): Only if fast user's I/O are used	9032 010 700

Table 19 SAM Drive Mating plug selection and ordering information

SAM Supply and its Accessories

Introduction

Procedure for selecting SAM Supply

Figure 15 shows the steps in selecting a SAM Supply, including a DB (Dynamic Braking) resistor and accessories. Proceed sequentially through the tasks listed in Figure 15, branching where indicated to the referenced pages that contain the details.

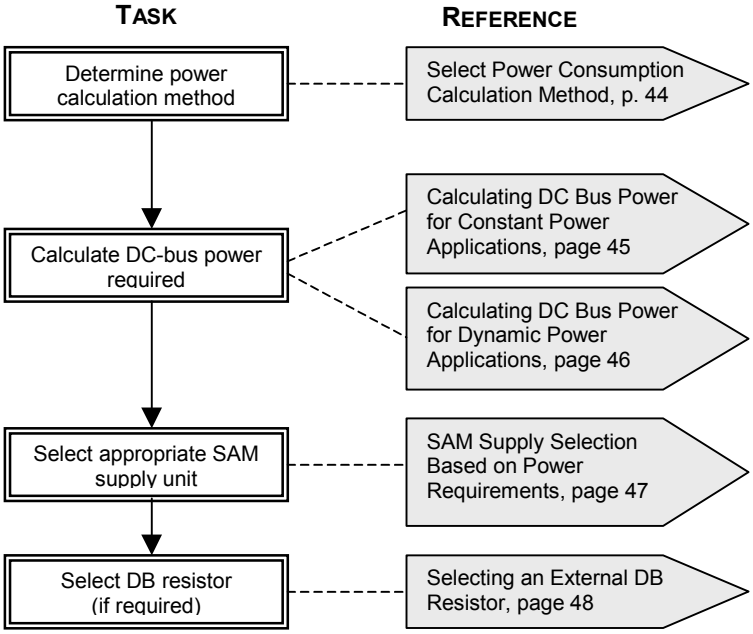

TASK
REFERENCE
Determine power calculation method
Select Power Consumption Calculation Method, p. 44
Calculate DC-bus power required
Calculating DC Bus Power for Constant Power Applications, page 45
Calculating DC Bus Power for Dynamic Power Applications, page 46
Select appropriate SAM supply unit
SAM Supply Selection Based on Power Requirements, page 47
Select DB resistor (if required)
Selecting an External DB Resistor, page 48

Figure 15 General Procedure for Selecting a SAM Supply

Supply Selection Strategy

This procedure results in selection of the lowest cost SAM Supply which will “do the job”. In some circumstances, when one considers the cost of carrying a spares inventory which includes several models of SAM units used in different machine types, the lowest total cost solution may be to select for all axes the lowest cost SAM Supply which satisfies the requirements for all machine types..

i

A 480 VAC rated SAM Supply can also be used at 400 VAC supply, provided that its drive power $P_{DRIVE\_RMS\_TOTAL}$ is derated to the value shown for the equivalent 400 VAC rated SAM Supply. On the other side the braking power $P_{BRAKE\_PEAK-TOTAL}$ does not have to be derated.

Ordering Information

SAM Supplies (including options and accessories) are determined by part number or by model number. Figure 16 illustrates the construction of a SAM Supply model

number based on the AC Supply voltage, its current rating and included options. The SAM Supply options described in this section are not field-installable. They must be installed at the factory. Once the model number is determined, locate the part number for selected SAM Supply model in Table 20.

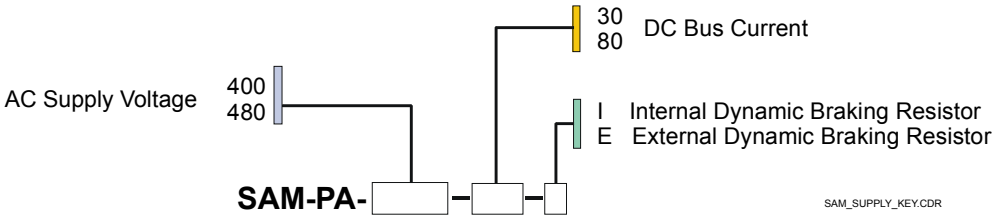


Figure 16 SAM Supply Model Numbering Key

			↓ Voltage rating ↓	
↓ optional features ↓			**SAM-PA-400…**	**SAM-PA-480…**
Current rating	DB Resistor			
30 ADC	internal	**…-30-I**	9032 010 441	9032 010 444
	external	**…-30-E**	9032 010 442	9032 010 445
80 ADC	external	**…-80-E**	9032 010 443	9032 010 446

Table 20 SAM Supply selection and ordering information

Example: SAM-PA-400-80-E, with part number 9032 010 443, is a SAM Supply Unit with the following characteristics and options:
- 480 VAC Supply Voltage rating
- 80 amp. continuous current rating
- Provisions for an External Dynamic Braking Resistor

Estimating DC Bus Power Requirement

General Information

Proceeding according to the SAM System component selection procedure (see Figure 1), load conditions for each motor in terms of velocity and torque have been defined. The power drawn by each SAM Drive from the DC Bus equals the power supplied to the load (i.e. the product of motor shaft torque and speed) plus electrical and mechanical losses in the motor, SAM Drive and wiring.

For example, a motor supplying its rated torque at stall (zero-speed) produces no mechanical power; therefore, the SAM Drive draws a small amount of power from the DC Bus, just for supplying the motor, drive and wiring losses.

An another characteristic of most multiaxis systems is that, thanks to the common DC-bus, the mechanical energy can be transferred from an axis that is decelerating to other axes that are accelerating. This saves tremendous energy consumption from the main supply, and reduces also heat production while braking.

Select Power Consumption Calculation Method

Depending on the application, DC Bus power drawn by each SAM Drive may be nearly constant, or fluctuate between positive and negative peak values. The first step is, therefore, to determine whether the application fits into the constant power or dynamic power category.

Constant Power Category Criteria

In constant power applications motors run at relatively constant speed and torque, requiring continuously nearly the same amount of power. During machine starts and stops, all motor speeds change at nearly constant acceleration within the same time span. Typical constant power applications include printing, winding/unwinding, extrusion and lamination processes with electronic gearing functions.

Dynamic Power Category Criteria

In dynamic power applications the machine performs a repetitive cycle during which motor speed and torque fluctuates between positive and negative peak values where motor torque is used mainly for accelerating and decelerating loads rather than for compensating friction effects. Typical dynamic power applications include handling and packaging machines with pick and place, cut to length and electronic cam functions.

Based on these definitions, select one of the following DC Bus power consumption calculation methods that best represents the intended application.

Calculating DC Bus Power for Constant Power Applications

The procedure for calculating DC Bus power required in constant power applications is as follows :

1. For each axis, calculate the continuous DC Bus power (P_{DRIVE}) supplied to the SAM Drive as follows :

   $P_{DRIVE}[W] = n_{SHAFT}[RPM] \times T_{SHAFT}[Nm] \times 0.105 \times 1/\eta_{AXIS}$

   where :

   n_{SHAFT} is the motor average speed in RPM

   T_{SHAFT} is the axis continuous torque (motor + load) in Newton-meters.

   For a winding axis driven by an induction motor, use either the spool empty (max. speed, low torque) or full (max. torque, low speed) condition, whichever is larger. Do not multiply max. speed by max. torque.

   η_{AXIS} is motor and drive efficiency. $\eta_{AXIS} \approx$ 0.85 if the motor is of synchronous (AC servomotor) type, or 0.75 if it is an asynchronous (induction) motor. Multiply this value by the gear efficiency if relevant.

2. For each axis, determine the rotational kinetic energy (E_{KIN}) as follows:

   $E_{KIN}[J] = J_{TOTAL}[kgm^2] \times (n_{SHAFT}[RPM])^2 \times 0.0055$

   where:

   J_{TOTAL} is the axis inertia (motor + load) in kilogram-meters^2 (as seen at the motor shaft)

   n_{SHAFT} is the motor average speed in RPM

3. Sum up the power supplied to all SAM Drives ($P_{DRIVE\_RMS\_TOTAL}$) as follows:

   $P_{drive\_rms\_total}[W] = P_{drive1} + P_{drive2} + P_{drive3} + P_{drive4} + ...$

In some applications - winding/unwinding for example - one motor may be operating with positive power (consuming power) while another is operating with negative power (generating power). In such situations, only the power losses (positive power) must be considered when designing the Feeding Section.

4. Record computed value of $P_{DRIVE\_RMS\_TOTAL}$ for subsequent use in Supply Unit selection.
5. Sum-up the kinetic energy (E_{KIN_TOTAL})of all axes as follows:

   $E_{KIN\_TOTAL}[J] = E_{KIN1} + E_{KIN2} + E_{KIN3} + E_{KIN4} + ...$
6. Compute peak braking power ($P_{BRAKE\_PEAK\_TOTAL}$) as follows :

   $P_{BRAKE\_PEAK\_TOTAL} \approx E_{KIN\_TOTAL} / (0.5 \times t_{STOP})$

   where:

   t_{STOP} is the braking (deceleration) process duration in seconds.
7. Considering the braking process duration (t_{STOP}) and interval between braking processes (t_{STOP_CYCLE}), determine the average braking power ($P_{BRAKE\_AVE\_TOTAL}$) requirement as follows:

   $P_{BRAKE\_AVE\_TOTAL} = E_{KIN\_TOTAL} / t_{STOP\_CYCLE}$

   In most constant power applications t_{STOP_CYCLE} may reach several minutes or even hours. When the braking process duration (t_{STOP}) is short, a much smaller t_{STOP_CYCLE} value must be used when selecting the Dynamic Braking Resistor. Use the following guidelines for selecting t_{STOP_CYCLE}:
   - When t_{stop} is less than 10 seconds, select t_{stop_cycle} = 10 seconds
   - When t_{STOP} is greater than 10 seconds, select $t_{STOP\_CYCLE} = t_{STOP}$
8. Record computed values of $P_{BRAKE\_PEAK\_TOTAL}$ and $P_{BRAKE\_AVE\_TOTAL}$ for use in SAM Supply and DB Resistor selection.

Calculating DC Bus Power for Dynamic Power Applications

This procedure for calculating DC Bus power required in dynamic power applications is based on some ”rules of thumb” which have proven to be convenient for most applications. It provides some safety margin as it is very common that while motors decelerate, their returned energy is immediately reused for accelerating other motors, reducing both the AC Supply furnished energy and dissipated energy. Simultaneous deceleration of all motors occurs only infrequently in an emergency stop condition. Using more exact analytical methods to detail all energy flow could possibly lead to lower power values and cost savings ; however, experience indicates there are many mechanical values not accurately known at machine design time which influence power needs more dramatically than regenerated energy available for reuse. For this reason this rather conservative ”rule of thumb” method is recommended. A results based power supply re-evaluation is generally warranted during comprehensive machine prototype testing.

1. Determine the worst-case cycle. Generally, power requirements are most severe at the highest production rate. If there is any doubt about this or if the machine can be adjusted for different production rates, this procedure should be repeated as many times as necessary in order to determine the worst case machine cycle.
2. Determine for each motor the peak positive and the peak negative shaft instantaneous power (P_{ACC_PEAK} and P_{DEC_PEAK}) as follows:

$P_{ACC\_PEAK}[W] \approx 0.105 \times n_{MAX}[RPM] \times (T_{ACC}[Nm] + T_{FRICTION\_MAX}[Nm]) \times 1/\eta_{AXIS}$

and

$P_{DEC\_PEAK}[W] \approx 0.105 \times n_{MAX}[RPM] \times T_{DEC}[Nm]$

where:

n_{MAX} is the maximum speed in RPM during acceleration/deceleration

η_{AXIS} is motor and drive efficiency. $\eta_{AXIS} \approx$ 0.85 if the motor is of synchronous (AC servomotor) type, or 0.75 if it is an asynchronous (induction) motor. Multiply this value by the gear efficiency if relevant.

T_{ACC} is the component of axis peak torque required to accelerate the (motor + load) inertia

T_{DEC} is the component of axis peak torque required to decelerate the (motor + load) inertia

$T_{FRICTION\_MAX}$ is the component of axis peak torque required to overcome (motor + load) friction.

3. Determine for each motor the positive "root-mean-square" power requirements (P_{ACC_RMS}) as follows:

   $P_{ACC\_RMS}[W] = 0.41 \times P_{ACC\_PEAK}[W]$

4. Determine for each motor the negative average power requirement ($P_{DEC\_AVG}[W]$) as follows:

   $P_{DEC\_AVG}[W] = 0.29 \times P_{DEC\_PEAK}[W]$

   Don't be surprised if these power values are smaller than the motor rated power as it is a typical phenomena for this type of applications.

5. Sum up the RMS power supplied to all SAM Drives ($P_{DRIVE\_RMS\_TOTAL}$) as follows:

   $P_{drive\_rms\_total} = P_{acc\_rms1} + P_{acc\_rms2} + P_{acc\_rms3} + ...$

   Record computed value of $P_{drive\_rms\_total}$ for subsequent use in Supply Unit selection.

   Sum-up the peak and average braking powers as follows:

   $P_{brake\_peak\_total} = P_{dec\_peak1} + P_{dec\_peak2} + P_{dec\_peak3} + ...$

   $P_{brake\_ave\_total} = P_{dec\_ave1} + P_{dec\_ave2} + P_{dec\_ave3} + ...$

6. Record computed values of $P_{brake\_peak\_total}$ and $P_{brake\_ave\_total}$ for use in SAM Supply and DB Resistor selection.

SAM Supply Selection Based on Power Requirements

Perform the following steps to select the appropriate SAM Supply unit based on DC Bus Power and Dynamic Braking power required:

1. Select the applicable segment of Table 17for the AC Supply voltage (i.e. 400 VAC) to be applied to the SAM Supply.
2. Within the selected AC Supply Voltage segment, select the appropriate subcolumn (i.e. <13 kW) of column "$P_{DRIVE\_RMS\_TOTAL}$" based on the previously computed and recorded RMS power ($P_{DRIVE\_RMS\_TOTAL}$) supplied to all SAM Drives.

3. Within the selected AC Supply segment, select the appropriate row (i.e. <26 kW) of column "$P_{BRAKE\_PEAK\_TOTAL}$" based on the previously computed and recorded peak braking power ($P_{BRAKE\_PEAK\_TOTAL}$) produced by all SAM Drives.
4. The contents of the cell at the intersection of the row selected in step 3 and column selected in step 2 (i.e. ...-30-E), designates the SAM Supply Unit current rating required for the application. If the contents of the selected cell is "...-30-?", a further evaluation must be made, proceed to step 5; otherwise, record the current rating and DB Resistor components of the Supply Unit model number.

↓ AC Supply Voltage ↓					
400 VAC			480 VAC		
SAM-PA-400-…			**SAM-PA-480-…**		
$P_{BRAKE\ PEAK\ TOTAL}$ ↓	↓ $P_{DRIVE\_RMS\_TOTAL}$ ↓		$P_{BRAKE\ PEAK\ TOTAL}$ ↓	↓ $P_{DRIVE\_RMS\_TOTAL}$ ↓	
	< 13 kW	< 35 kW		< 16 KW	< 42 KW
< 8.5 kW	**...-30-?**	**...-80-E**	< 8 KW	**…-30-?**	**…-80-E**
< 25 kW	**...-30-E**	**...-80-E**	< 28 KW	**…-30-E**	**…-80-E**
< 62 kW	**...-80-E**	**...-80-E**	< 74 KW	**…-80-E**	**…-80-E**

Table 21 SAM Supply Model Selection Chart

5. If the model number component selected in step 4 was "...-30- ?"), it is necessary to define if the built-in resistor can handle the avarage braking power or not:
   – If the previously computed average braking power ($P_{BRAKE\_AVE\_TOTAL}$) is greater than 70 W, select "30-E" for external Dynamic Braking Resistor.
   – If ($P_{BRAKE\_AVE\_TOTAL}$) is less than or equal to 70 W, select "30-I" for internal Dynamic Braking Resistor, unless cooling capacity within the enclosure cannot accommodate 70 Watts from an internal DB resistor.
6. Record the complete SAM Supply model number selected from Table 21 (i.e. SAM-PA-480-E).

Selecting an External DB Resistor

When an External DB Resistor is Required

When a SAM Supply without a built-in DB resistor (designated by "...-E" in the model number) has been selected, the user must provide an external DB Resistor from among those available from ACC.

About SAM System DB Resistors

These DB resistors incorporate an "ID resistor" which informs the SAM Supply of the unit's power rating. The SAM Supply requires this ID resistor for power dissipation monitoring and DB resistor overload protection. Thanks to this feature, no manual adjustment is required for adjusting the selected DB resistor power.

DB Resistors are supplied with a 3-meter length of shielded cable attached to the DB Resistor and a connector kit for attaching to the SAM Supply end. One end of the cable is left unterminated to facilitate routing the cable and to permit trimming to required length before installing the supply end connector. Refer to {} for dimensions of DB Resistors.

Selection and Ordering Procedures

The DB Resistor must accommodate the average braking power ($P_{BRAKE\_AVE\_TOTAL}$) which determines the resistor power rating and the peak braking power ($P_{BRAKE\_PEAK\_TOTAL}$) which determines the resistor's ohmic value. Referring to Table 22, perform the following steps to select an appropriate DB Resistor :

1. In the column labeled "$P_{BRAKE\_AVE\_TOTAL}$", select the lowest wattage rating which is greater than the previously computed average braking power ($P_{BRAKE\_AVE\_TOTAL}$). If $P_{BRAKE\_AVE\_TOTAL}$ for the application exceeds the largest rated DB Resistor power rating listed, contact an ACC Motion Applications Center for assistance.
2. Select the line depending upon SAM Supply used.
3. Record the corresponding part number (and ohm value) for the DB resistor selected.

	↓ $P_{BRAKE\_AVE\_TOTAL}$ ↓		
↓ SAM Supply used ↓	0 to 400 W	0 … 800 W	0 … 1600 W
SAM-PA-400-30-E	9032 010 704 (R = 16.8 Ω)	9032 010 704 (R = 16.8 Ω)	
SAM-PA-400-80-E		9032 010 704 (R = 16.8 Ω)	9032 010 704 (R = 16.8 Ω)
SAM-PA-480-30-E	9032 010 704 (R = 16.8 Ω)	9032 010 704 (R = 16.8 Ω)	
SAM-PA-480-80-E		9032 010 704 (R = 16.8 Ω)	9032 010 704 (R = 16.8 Ω)

Table 22 External DB Resistance Selection and Ordering part numbers

SAM Supply Unit Accessories

General Information

PAM and SAM System cables and mating connectors are not systematically shipped with each SAM Drive, and must be ordered separately. As for SAM Drives the information below assumes that all ready-made cables and accessories are used.

Users who decide purchasing cables, connectors, and wiring accessories from a third party, will find detailed connector information in Appendix A - Mating Plugs Specifications, and cable information in Appendix B - Cable.

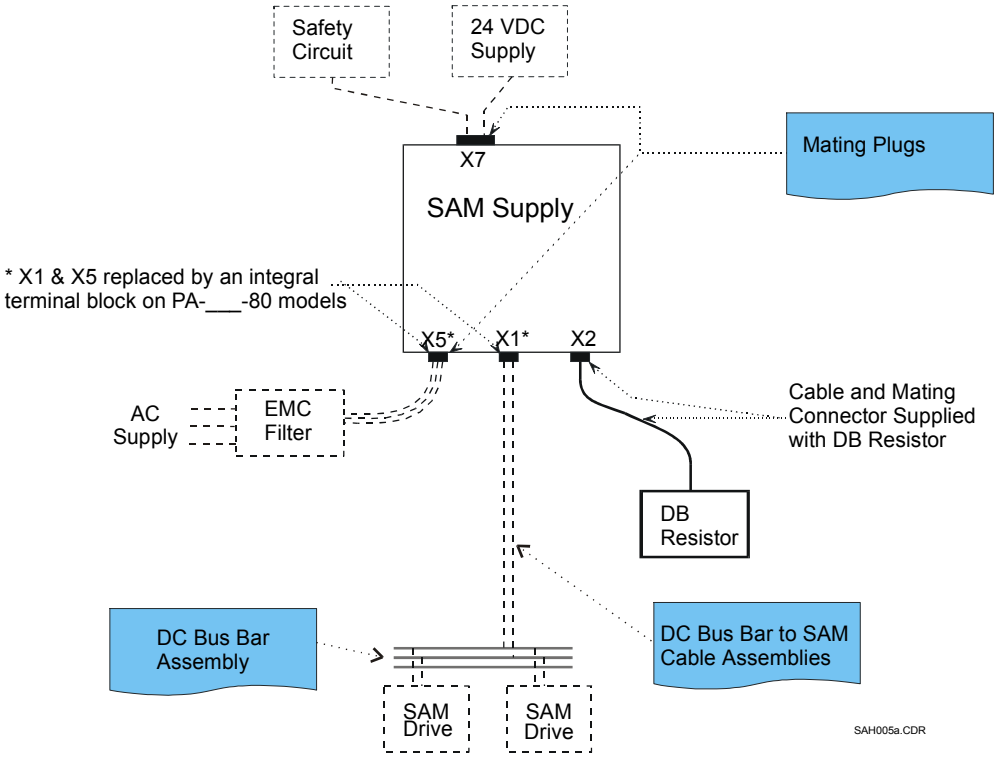


Figure 17 SAM Supply Mating Connector Configuration

Selecting Mating Plugs

When SAM System Ready-made cables and DC-bus Bars are used, only the plugs below must be ordered in addition, depending upon SAM Supply type.

If SAM-PA-…-30-… is used, order:
- plug X5, p/n 9032 011 016 (AC supply)
- plug X7, p/n 9032 010 792 (24 VDC supply & safety interlocks)

If SAM-PA-…-80-… is used, order:
- plug X7, p/n 9032 010 792 (24 VDC supply & safety interlocks)

DC-bus Bar

General Information

The DC Bus distributes DC Power at high voltage and current levels from a SAM Supply to SAM Drives in a PAM with SAM system.

The PAM & SAM System offer a new, innovative DC-bus Bar. Benefits for users are:
- Compact: It requires only 40 mm of mounting panel height
- Safe: It is inherently IP20 protected; no cover to put and remove
- Easy-to-use: Lock-on connectors; screw-driver required only for disconnecting
- One bus bar accommodates up to 12 SAM units (DC+, DC-, PE)
- Provides for 12 additional PE connections, to be used for motor PE connection
- Possibility to cascade several bus bars

In addition to the bus bar itself, a range of preconfectionned cables are available that fit to all SAM units.

DC-bus bar description

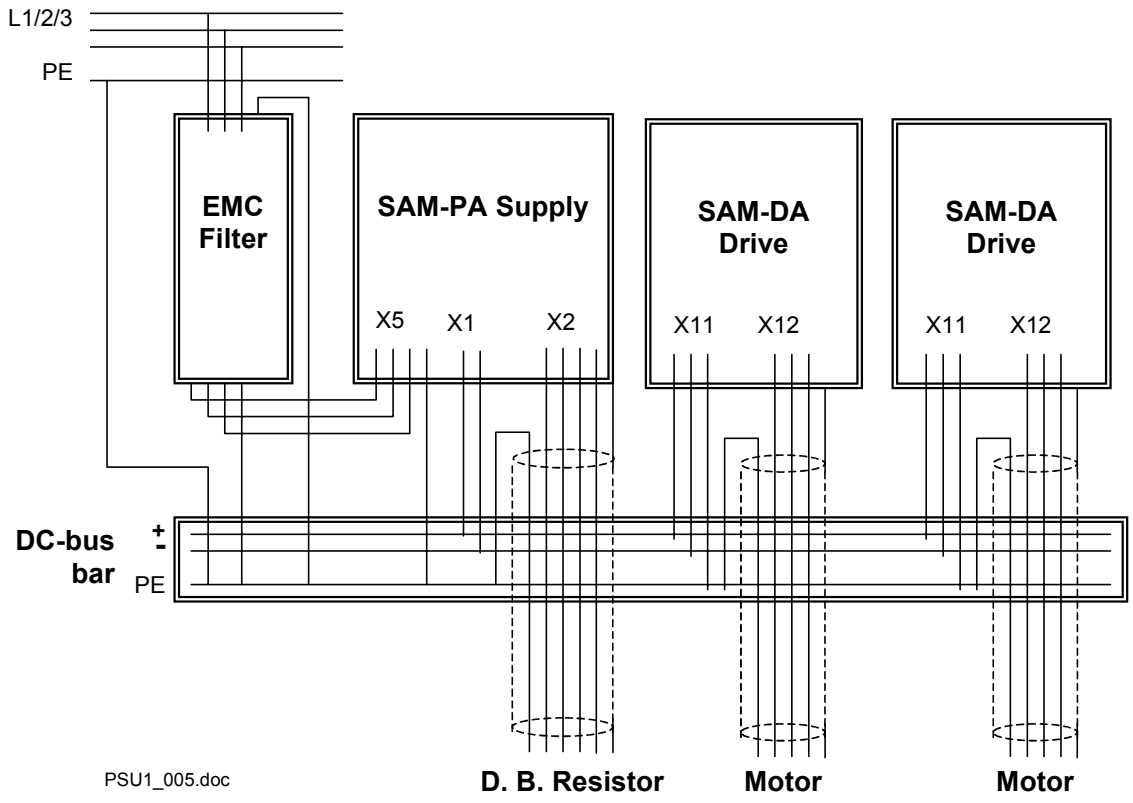


Figure 18 DC bus bar wiring diagram

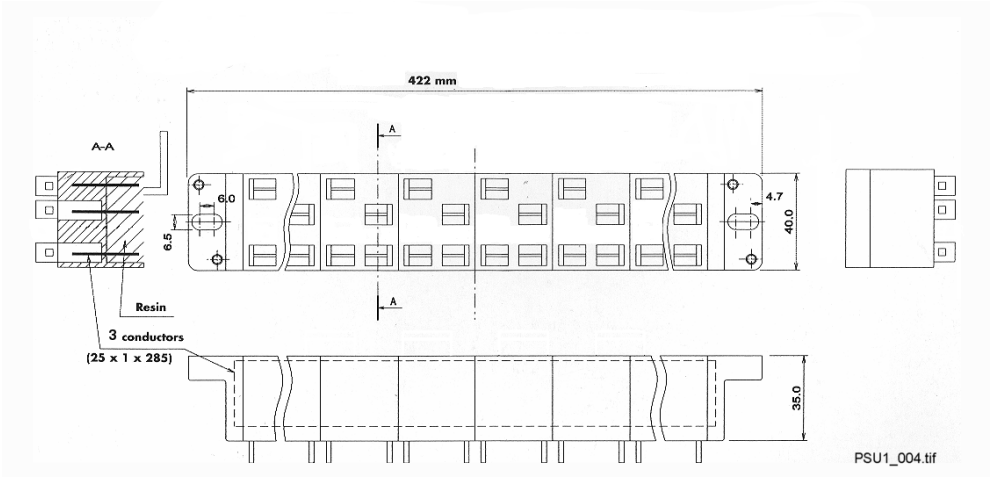


Figure 19 DC-bus bar outlines

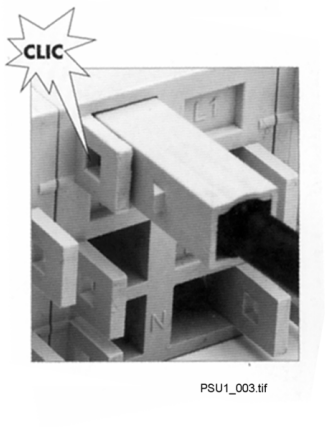


Figure 20 Contact principle

Nb. of poles	3 poles: – DC-bus + – DC-bus - – PE
Max. current at any outlet	30 A_{rms} (with 4 mm^2 wire and plug) 40 A_{rms} (with 6 mm^2 wire and plug)
Max. internal current	250 A_{rms}
Short-circuit withstanding	61 kA peak 29.6 kA for 90 ms 10 kA_{rms} for 1 s
Insulation	660 VAC
Protection degree	IP20
Number of contacts	12 contacts for DC-bus +, 12 contacts for DC-bus -, 24 contacts for PE
Outlines	Length: 422 mm Width: 40 mm Height: 35 mm (without plugs)
Weight	0.9 kg

Table 23 DC-bus bar data

DC-bus bar and Cables available - Ordering part numbers

DC-bus bar

The DC-bus bar itself can be ordered as p/n 9032 011 935.

SAM Supply to DC-bus bar cable assemblies

If SAM-PA-…-30-… is used, use following ready-made SAM Supply to the DC-bus bar cable:

– P/n 9032 011 940: DC-bus bar to SAM-PA-30 cable, 2 x 4 mm^2, 400 mm

If SAM-PA-…-80-E is used, use following cable(s):

– P/n 9032 011 939: DC-bus bar to SAM-DA-28/50 cable, 3 x 6 mm^2, 400 mm

Use 2 such cables, as required for accommodating currents up to 80 A. One cable only is acceptable only if the AC supply overload protection is adjusted at 32 A_{rms}, reducing thus the SAM Supply output current to 40 A_{dc}.

Cable Assemblies for cascading several DC-bus Bars

Ready-made cable connections for cascading several DC-bus bars:

- P/n 9032 011 941: DC-bus bar to DC-bus bar cable, 3 x 6 mm^2, 150 mm
- P/n 9032 011 942: DC-bus bar to DC-bus bar cable, 3 x 6 mm^2, 800 mm

SAM Drive to DC-bus Bar Cable Assemblies

Refer to the “DC-bus bar Cables available and Ordering part numbers” section, on page 41

Additional DC-bus Capacitors

Additional DC Bus capacitance may be used as energy back-up, which make a controlled machine stop possible also when the main AC supply drops.

Ask your SAM System supplier for assistance.

Quick DC-bus Discharge

The SAM System built-in discharge circuitry guarantees that no dangerous voltage remains after a maximum discharge time of 60 seconds.

Should a quicker discharge time be required, or are Additional DC-bus Capacitors used, then a Quick DC-bus Discharge system is required. It requires a relay and a power resistor, as shown in Part 3 - “Safety and Protective Functions”.

Feeding Section

General

Feeding Section Definition

This section discusses sizing and selection of components within the Feeding Section, which were not addressed in the previous section SAM Supply and Accessories. Components that belong to the Feeding Section are defined in IEC / EN 61800-2 “Semiconductor Power Converters for Adjustable Speed Electric Drive Systems”. The Feeding Section of a PAM with SAM Power Drive system includes all components of the AC Supply circuit between the AC Supply mains and the SAM Supply unit including:

- EMC filter
- inrush current limiting components
- transformer (optional)
- AC main contactor
- short circuit, overload and other protection devices (circuit-breaker or fuses)

In addition the PAM and SAM System requires a 24 VDC supply.

Local, national or factory regulations may require inclusion of additional protective components beyond those covered in this chapter. The system designer must be cognizant of and comply with applicable regulations and standards.

Special Applications

Contact an ACC Motion Applications Center for technical assistance if your application requires special configurations that are beyond the scope of this manual such as:

- Battery or uninterruptable DC power supply operation
- Single phase AC Supply for lower cost low power applications

Basic Feeding Section Configuration

Figure 21 illustrates the basic Feeding Section circuit for a PAM with SAM System.

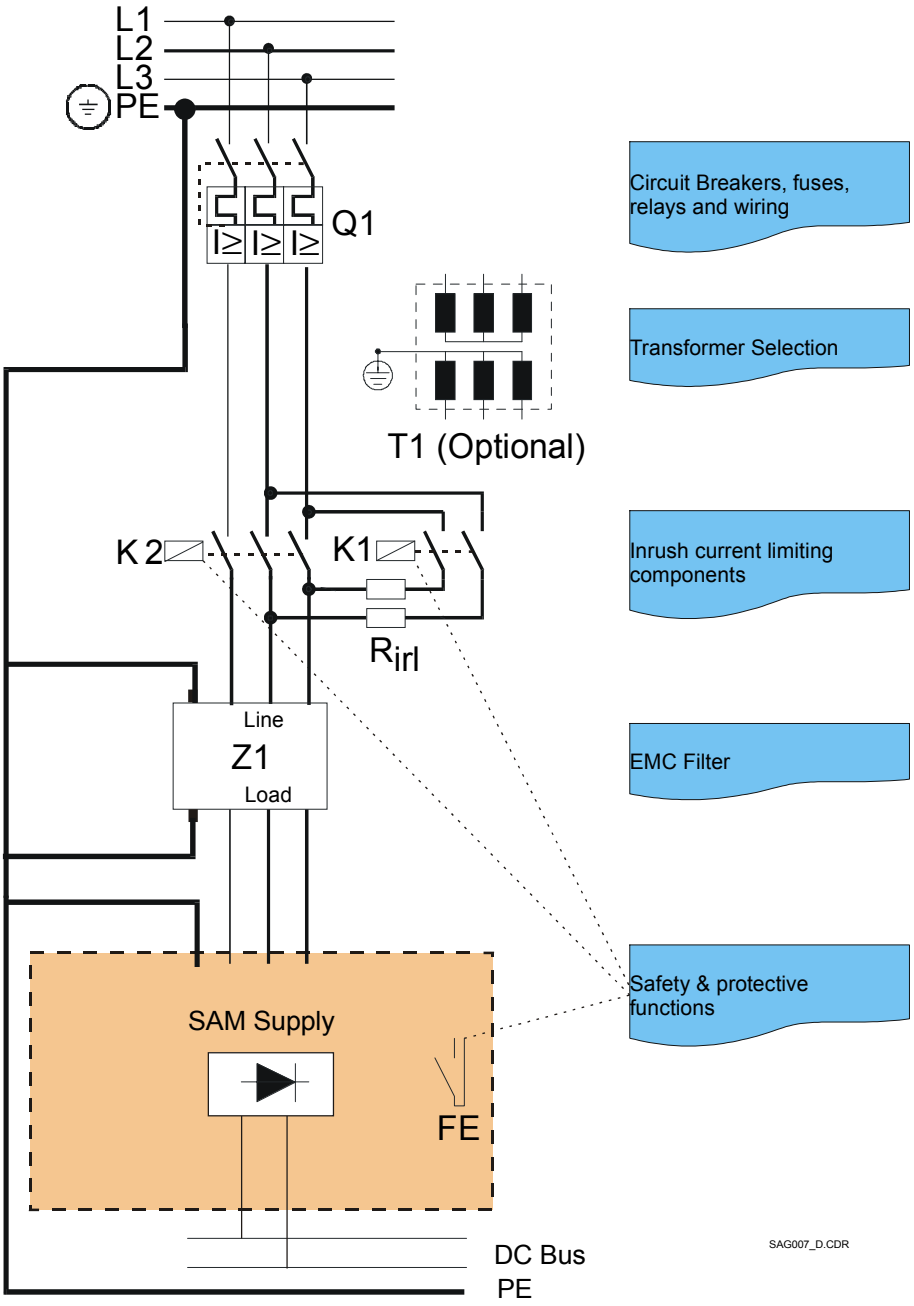


Figure 21 Basic Feeding Section Components

The functions performed by the components are as follows:

symbol	description
L1, L2, L3	AC Supply
PE	Protective Earth ground
Q1	Circuit breaker - provides overload and short circuit protection. Fuses may also be used for this function.
K1	AC starting relay - switches AC Supply power to the entire Power Drive system during startup. K1 is de-energized once the DC Bus capacitance has charged.
K2	Bypass relay - K2 is energized once the DC Bus capacitance has charged, before K1 is de-energized
Rirl	Inrush current limiting resistors - used at AC Supply switch-on to limit input current peaks during initial charging of the DC Bus capacitors. When AC power is first applied, the starting relay (K1) feeds the SAM Supply unit through in-rush current limiting resistors Rirl. (See: Inrush Current Limiting Components, page55).
T1 (optional)	Transformer - converts non-standard AC supply voltages to voltage level required by SAM Supply. T1 is an optional component which is not used in every application. (See AC Supply and Earthing, page 16).
Z1	EMC line filter - suppresses transmission of electrical noise generated within power drive system into AC Supply. (See below)

Table 24 Basic Feeding Section Component list

For additional information on selecting Feeding Section components, refer to the topics listed in Figure 21.

EMC Filter

The EMC Filters listed in below provide state-of-the-art filtering for PAM & SAM Systems. These filters meet the latest EMC standards (UL 1283 and EN 133200) and are rated for use at AC Supply voltages up to 480 VAC at 50° C and at frequencies from DC to 60 Hz.

Select an EMC filter model depending upon the SAM Supply type used:

If SAM-PA-…-30-… is used, use following EMC filter:
- P/n 9032 011 149: EMC Filter type FN258-30-07

If SAM-PA-…-80-E is used, use following cable (2 pieces in parallel)::
- P/n 9032 011 150: EMC Filter type FN258-75-34

When more than 8 SAM Drives are connected to one SAM Supply, and when motor cables are over ~5 meter each, These EMC filters may be insufficient for filtering the earth current that is induced into the motor cables. Ask your SAM System supplier for assistance.

Inrush Current Limiting Components

General Information

When a SAM System is powered-on, the DC-bus capacitors within all units have to be loaded. At the first instant they represent a short-circuit behind the SAM Supply rectifier. As only the AC Supply impedance then limits the peak current, it generally

reaches values that are unacceptable for the rectifier. Such high peak currents are generally not acceptable either for the AC supply protective devices.

For this reason a 2-step switch-on system must be used, as shown in Figure 21. This requires Inrush Current Limiting Resistors to be inserted into the AC supply. These resistors are used only during the DC-bus voltage rise.

Inrush Current Limiting Resistors Selection

The Inrush Current Limiting Resistor unit, p/n 9032 010 785, is currently specified for use with all SAM Supply models. It contents three 50 Ω / 50 W resistors within one housing.

Inrush current limiting resistors are sized based upon the following restrictions concerning their use in the application:

- Time between two (2) successive power-on operations is never less than ten (10) seconds
- The short circuit sustaining time never exceeds 0.3 seconds.

Ask your PAM and SAM System supplier, should any of these criteria not be fulfilled.

We recommend utilizing the host PC/PLC or some I/Os of the PAM & SAM System to assure compliance with the power-on cycle repetition time and short circuit sustaining time requirements. Refer to Part 3 - ”Safety and Protective Functions” for details on how these protective functions may be implemented.

Low Cost Inrush Current Limitation Using NTC Resistors

In some applications where I_{L_MAX} is less than 10 A_{rms}, the inrush current limiting resistors and starting relay K1 can be replaced by NTC (Negative Temperature Coefficient) resistors placed in series with relay K2 (See Figure 21).

Using NTC Resistors is simpler and less expensive than the resistors and starting relay solution. This approach is not recommended for highly dynamic applications, where they may never reach their working temperature, thereby preventing motors from reaching their peak velocity. Contact your SAM System supplier for additional information or assistance in the application of NTC resistors for inrush current limiting.

Input Current Computation

All Feeding Section components are sized based on the RMS power ($P_{DRIVE\_RMS\_TOTAL}$) actually consumed by the Power Drive System, rather than SAM Supply unit or transformer current ratings which may be considerably higher. This approach provides better overload protection and frequently some cost savings. Proceed as follows:

1. Determine the lowest available AC Supply voltage (U_{V_MIN}). Generally decreasing the rated AC Supply voltage by 10% provides a good result.
2. Using the RMS power supplied to all SAM drives ($P_{DRIVE\_RMS\_TOTAL}$) computed during Supply Unit selection (see "Estimating DC Bus Power Requirement" on page 43),compute the maximum RMS primary current (I_{L_MAX}) required as follow:

I_{l_max}[Arms] = 0.57 _ $P_{drive\_rms\_total}$[W] / U_{v_min}[V_{rms}]

3. If a transformer is used (and only in that case), increase I_{L_MAX} by 4% to accommodate transformer losses.

4. Record $I_{L\_MAX}[A_{RMS}]$ for use in component sizing calculations.

Optional Transformer

Requirements

A transformer is required under any of the following circumstances:
- The AC Supply voltage exceeds the maximum rated voltage that may be applied to a PAM with SAM system (see "Using SAM at higher voltages" on page 17).
- The AC Supply is not a three phase, four wire system with solidly earthed neutral (see "Earthing Requirements" in 18)

A transformer powering one or more SAM Supply units must meet the following requirements:

1. Isolation transformers and non-isolation transformers (autotransformers) are allowed. However, if the AC Supply is not a three phase, four-wire system with solidly earthed neutral, an isolation transformer must be used.
2. For isolation transformers only (see "{Interfacing an Isolation Transformer}") - the transformer secondary must be wired in a ”Wye”, configuration and the star point, which is the secondary’s neutral, must be solidly earthed with a short, thick connection to protective earth. The primary may be either “Delta” or “Wye” connected.
3. For auto-transformers only (see "{Interfacing auto-transformers}") – the transformer must be “Wye” connected and the star point must be solidly grounded with a short, thick connection to protective earth ground.
4. Correct secondary voltage - The transformer secondary voltage must be specified at no-load condition. This is to avoid overvoltage at the SAM Supply unit input when the AC Supply voltage reaches its +10% tolerance point and the transformer is not loaded. We recommend specifying also a voltage drop of 2 to 4% at nominal load. **Be aware**: These requirements are not usual in transformer business, and must be clearly specified.
5. Correct power rating - Make sure the transformer power rating is correct for the load; not higher, not lower. Power rating should be determined by the power actually consumed by the Power Drive System ($P_{DRIVE\_RMS\_TOTAL}$) rather than by the SAM Supply unit size (see “Estimating DC Bus Power Requirement”, page 43).

Circuit Breaker, Fuses, Relays and Wiring

Choose these components - as as well as other machine parts, - according to international standards and local regulations. Chose their current rating based on I_{L_MAX} (see “Estimating DC Bus Power Requirement”, page 43).

When selecting fuses, circuit breakers and other overload protection devices, choose a rating slightly higher than I_{L_MAX}. Choose a rather slow reacting protection device whose reaction time fits the machine cycle time. Select circuit breakers with a short circuit threshold as high as possible (i.e. 8 times I_{RATED}).

When selecting other Feeding Section components such as wire, terminals and EMC filters, select devices with current ratings greater than I_{L_MAX}.

24 VDC Supply

General Information

The 24 VDC supply provides a low voltage power source which each SAM Drive, SAM Supply and PAM (rack mounted models only) utilizes to develop their internal supply voltages. On units equipped with cooling fans, the fans are powered by 24 VDC. The 24 VDC supply may also be utilized as a power source for:

- Operating electro-mechanical brakes
- Devices controlled by the User I/O
- Other system or machine functions

Requirements

As a general statement, the 24 VDC power supply should comply with IEC / EN 61131-2 Standard, “Programmable Controllers". It means that the voltage must be between 19.2 and 30.0 V (including all AC components). An existing, unregulated system/machine supply may be utilized as long as the requirements are satisfied.

The 24 VDC supply must have its negative pole solidly earthed, either at its terminals or close to the SAM Drives.

Estimating SAM System Current Requirement on 24 VDC Supply

Table 25 should be used to estimate the 24 VDC current requirements of a PAM and SAM system. The current values listed do not include the current consumed by the user’s I/O devices, electromechanical brakes, and alike. The peak values listed occur momentarily upon switch-on of 24 VDC power.

Item	Nominal current need [Adc]	Peak current [Adc]	Comment
SAM Drive (any size)	1.0	2.5	any model SAM drive with or without options
SAM Supply (any size)	1.0	2.5	any model SAM Supply
PAM-F51 Full System	0.8	1.3	
PAM Full System	1.2	???	worst case with Profibus-DP interface slightly less with other interface options

Table 25 SAM 24 VDC current requirements

System Enclosure

Cabinet Selection

General

The enclosure housing a PAM with SAM system serves several purposes including:
Environmental protection and security for the equipment
Suppression of EMI/RFI emissions

This section presents some basic guidelines and items for consideration when selecting a system enclosure.

Environmental Protection and Security Considerations

PAM with SAM system components are rugged industrial devices; however, their environmental ratings and limits must be respected to insure long term, reliable operation. The accumulation of dust and other deposits can hamper transfer of heat from the equipment resulting in higher internal operating temperature and decreased output capacity. Electrically conductive deposits in the presence of moderately high voltages (up to 780 volts) present in the equipment can cause faults and failures in the system.

Select an enclosure with the appropriate level of sealing and air filtering for the environment where the enclosure is located. An enclosure, with the proper access control measures and safety interlocks, can provide security for the equipment. In some locations, safety interlocks are required by law.

EMI/RFI Considerations

As the SAM units have been tested on EMC (Electromagnetic Compatibility), the "Emitted Radiation" test has been performed (and standard requirements met) with open cabinet doors. Nevertheless we recommend following considerations below.

Power Drive Systems have the potential to generate high levels electromagnetic emissions. A properly designed and installed cabinet is very effective in reducing radiation and in satisfying EMC regulations. In order to effectively limit EMI/RMI emissions, the cabinet construction must satisfy the following criteria:
The enclosure must be made of metal
There must be a nearly continuous, uninterrupted metallic bond along the juncture of all planes that form the exterior surface of the cabinet. Cabinets assembled with continuous welds are ideal. For cabinets assembled by other means (i.e. spot welds, screws, etc) no gap of more than 5 cm in length is allowed along the line of intersection of the planes. This means, for example, that a cabinet assembled with screws must have a screw every 5 cm joining the sides, top and bottom surfaces.
Access doors must be equipped with EMI/RFI gaskets.
The backpanel (equipment mounting panel) must be bare (unpainted) the areas beneath where the PAM, SAM Drives, SAM Supplies and EMI filters are mounted, providing intimate metallic contact between the units and backpanel.

Cooling Equipment

General

The failure to provide adequate cooling for a power drive system is one of the leading causes of unsatisfactory performance and one of the most difficult deficiencies to correct after a system has been installed. A detailed presentation on thermal load calculation and cooling equipment sizing is beyond the scope of this manual; however, please consider the following points when sizing cooling equipment for the system:
Use the highest expected ambient temperature at the location where the system will be installed for calculating cooling required.
Do not neglect the contribution of transformers. Although their efficiency is very high, they transfer a large amount of power and the heat they create can be considerable.
Extra cooling capacity is relatively inexpensive to purchase, but costly to add after the system has been completed.

Appendix A - Mating Plugs Specifications

Table 26, Table 27, Table 28, and Table 29 summarize the functions of all PAM and SAM System plugs, and provides supplier references. This information is shown for users, whose strategy is purchase cables and plugs directly, or via third parties.

Figure 22 and Figure 23 show drawings that specify how mating plugs must be marked.

Conn. code	Unit	Function	p/n	Supplier reference
X1	PAM (all except PAM-ISA)	RS232 Port to Servicing-PC	505.3032	Connector ITT Cannon DA-15P-K87-K91
			505.3042	Metalized housing HADIMEC 1715 OM 38T 001
	PAM-ISA	RS232 Port to Servicing-PC		Connector Deltron HD 15 PZ
			9032011005	Metalized housing HADIMEC 1709 OM 38T 001
X2	PAM-F26 Full System (with RS422 port)	RS 422 port	9032010699	Connector ITT Cannon DE-9P-K87-K91, Metalized housing HADIMEC 1709 OM 38T 001
X8	PAM (all)	"Fatal Error" output	505.5402	Weidmüller BL 3.5/2F SN OR option 160664 (markings to drwg. 080.4151)

Table 26 PAM Mating Plugs

Conn. code	Unit	Function	p/n	Supplier reference
X1	SAM-PA-…-30-…	DC-bus output	9032011012	Weidmüller STV S 2 S S, option 161195 (drwg. 080.4119)
X2	SAM-PA-…--…-E	DB resistor output	9032011015	Weidmüller STV S 4 S s, option 161201 (drwg. 080.4122)
X5	SAM-PA-…-30-…	AC supply input	9032011016	Weidmüller STV S 4 S B, option 161202 (drwg. 080.4123)
X7	SAM-PA-…-…-… (all)	24 VDC supply and status/safety I/Os	9032010792	Phoenix Contact MSTB 2,5/10-STF, option 17 86 91 2 (markings to drwg. 080.4127)

Table 27 SAM Supply Mating Plugs

Unit	Function	p/n	Supplier reference
EasyBus	Fiber-to-Fiber Optical Coupler	9032011148	HUBER & SUHNER FSMA-FSMA-C001 # 650884.22
DC-bus bar	Bus bar	9032011935	Auxel 96011X
	1 - 2.5 mm^2 plug	9032011936	Auxel 96530
	4 - 6 mm^2 plug	9032011937	Auxel 96529

Table 28 Cabling Accessories Plugs

Conn. code	Unit	Function	p/n	Supplier reference
X11	SAM-DA-…-07…-…-… SAM-DA-…-14…-…-…	DC bus supply input	9032011014	Weidmüller STV S 3 S B, option 161199 (drwg. 080.4121)
X12	SAM-DA-…-07…-…-… SAM-DA-…-14…-…-…	Motor output	9032011013	Weidmüller STV S 3 S S, option 161198 (markings to drwg. 080.4120)
X13	SAM-DA-…-…-…(all)	Motor thermal protection input	9032011008	Phoenix Contact MSTB 2,5/3-STF, # 17 86 84 4 (markings to drwg. 080.4124)
X14	SAM-DA-…-…B-…-…	Brake output	9032010791	Phoenix Contact MSTB 2,5/5-STF, #17 86 86 0 (markings to drwg. 080.4125)
X17	SAM-DA-…-…-…(all)	24 VDC supply and status/safety I/Os	9032011010	Phoenix Contact MSTB 2,5/6-STF, # 17 86 87 3 (markings to drwg. 080.4126)
X23	SAM-DA-…-…-P4N-…	Analog input	9032011104	Connector ITT Cannon DB-25P-K87-K91, Metalized housing HADIMEC 1725 OM 38T 001
	SAM-DA-…-…-P5N-…	Encoder/EnDAT input		
X24	SAM-DA-…-…-P4N-…	Resolver input	9032010699	Connector ITT Cannon DE-9P-K87-K91, Metalized housing HADIMEC 1709 OM 38T 001
	SAM-DA-…-…-P5N-…	Resolver input Analog input		
X31	SAM-DA-…-…-…-E	IN2 / IN3 inputs OUT1 ouput	9032011072	Weidmüller BL 3.5 1*P3.5 5P, option 160667 (markings to drwg. 080.4152)
X32	SAM-DA-…-…-…-E	IN1 Fast input Alternative connection for IN2 / IN3 / OUT1	9032010700	Connector ITT Cannon DE-9S-A197-K91, Metalized housing HADIMEC 1709 OM 38T 001
	SAM-DA-…-…-…-F	All user inputs and outputs	9032010793	Weidmüller BL 3.5 1*P3.5 16P, option 160678 (markings to drwg. 080.4128)

Table 29 SAM Drive Mating Plugs

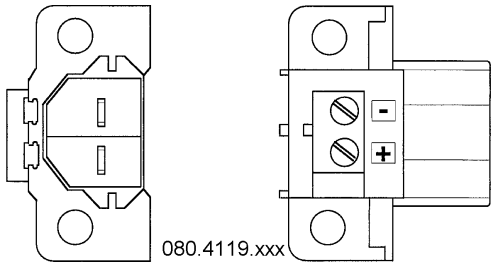
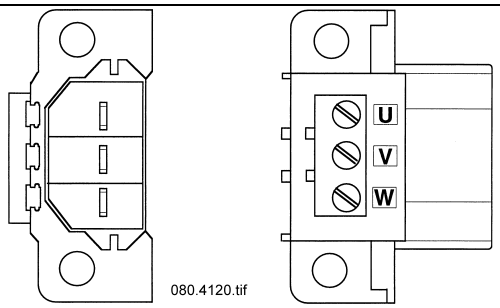
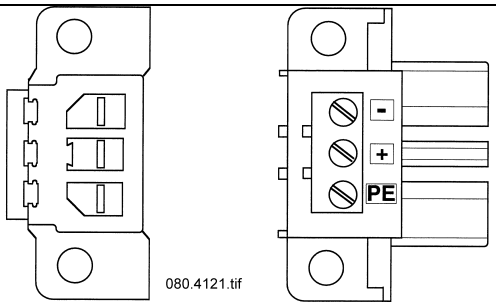
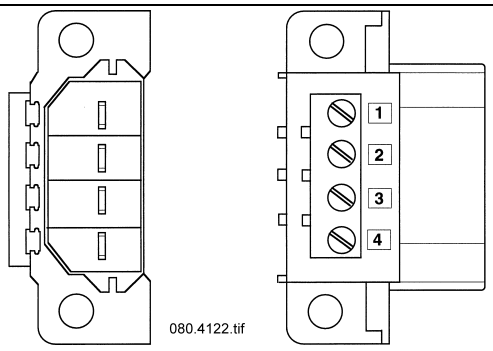
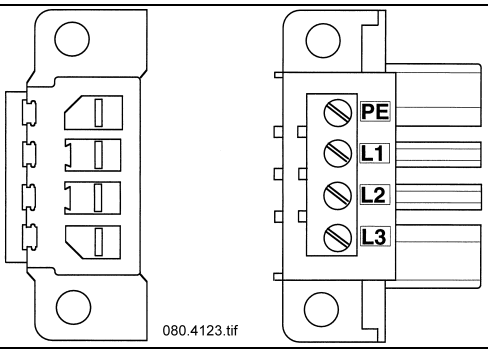
Drawing 080.4119	
Drawing 080.4120	
Drawing 080.4121	
Drawing 080.4122	
Drawing 080.4123	

Figure 22 Power mating plug drawings for marking specification

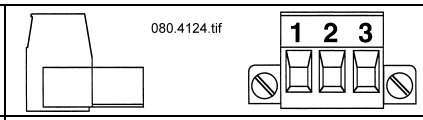
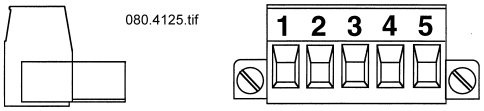
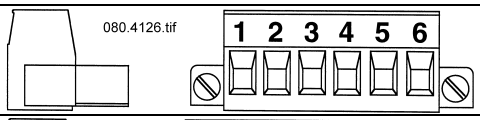
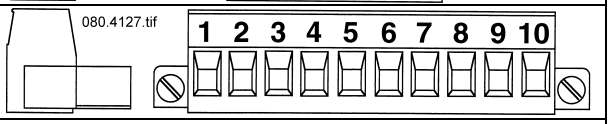
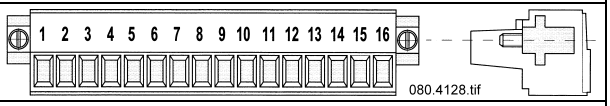
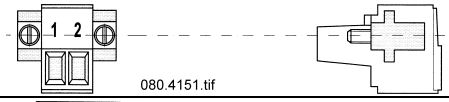
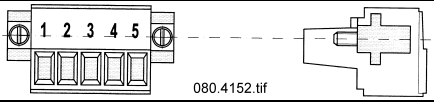
Drawing 080.4124	
Drawing 080.4125	
Drawing 080.4126	
Drawing 080.4127	
Drawing 080.4128	
Drawing 080.4151	
Drawing 080.4152	

Figure 23 Signal mating plug drawings for marking specification

Appendix B - Cables

Table 30 shows all cables that are used with PAM & SAM System.

Cable	Type	P/n	Supplier references
8-conductor motor cable	1 mm^2	9032011033	LIDALCO # 418410205 EUROFLEX COMBI CY 4x1,0 + 2x(2x0,5)
	1.5 mm^2	9032011034	LIDALCO # 418415205 EUROFLEX COMBI CY 4x1,5 + 2x(2x0,5)
	2.5 mm^2	9032011035	LIDALCO # 418425275 EUROFLEX COMBI CY 4x2,5 + 2x(2x0,75)
	4 mm^2	9032011036	LIDALCO # 418442127 EUROFLEX COMBI CY 4x4 + (2x1,0) + (2x0,75)
	6 mm^2	9032011037	LIDALCO # 418460210 EUROFLEX COMBI CY 4x6 + 2x(2x1,0)
	10 mm^2	9032011038	LIDALCO # 418461210 EUROFLEX COMBI CY 4x10 + 2x(2x1,0)

Table 30 PAM and SAM System recommended Cables

Appendix C - DC-bus alternatives

For small systems (i.e. a PA-…-30 and 1 to 3 SAM Drives) DC Bus power can be distributed using daisy chained wiring from the SAM Supply to SAM Drives in combination with a simple earth ground rail.

As an alternative to the SAM System DC-bus bar, manufacturers including Phoenix and Weidmüller offer power distribution components suitable for distributing DC Bus power in a PAM with SAM system.